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Ahn et al.

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(54) **LIGHTING DEVICE, LIGHTING SYSTEM AND WEARABLE DEVICE HAVING IMAGE PROCESSOR**

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(73) Assignee: **LG Electronics Inc.**, Seoul (KR)

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G02B 27/28 (2006.01)
G02B 27/01 (2006.01)

(52) **U.S. Cl.**

CPC ***H05B 37/0227*** (2013.01); ***H05B 37/0272*** (2013.01); *G02B 27/0172* (2013.01); *G02B 27/281* (2013.01)

(58) **Field of Classification Search**

CPC G06T 2207/10024; G06T 7/004
USPC .... 315/149–159, 247, 185 S, 209 R, 224, 315/291, 307–326; 359/381, 379, 385, 390, 359/387, 630
See application file for complete search history.

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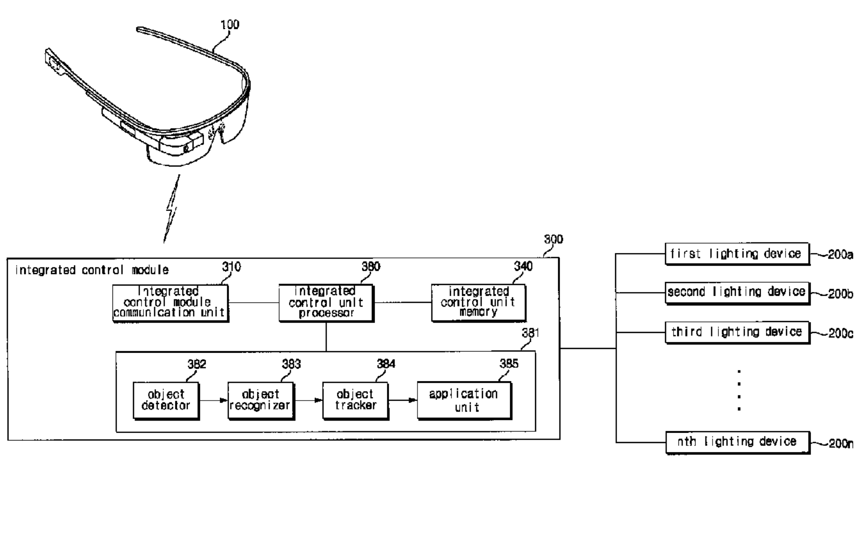
(57) **ABSTRACT**

A lighting system includes: a plurality of lighting devices each including one or more light emitting units; and an integrated control module; and an integrated control module that communicates with the wearable device with at least one camera, receives an image of a user's eye captured by the camera, detects a pupil image based on the image, and controls the number of lighting devices to be activated among the plurality of lighting devices based on the pupil image.

14 Claims, 24 Drawing Sheets



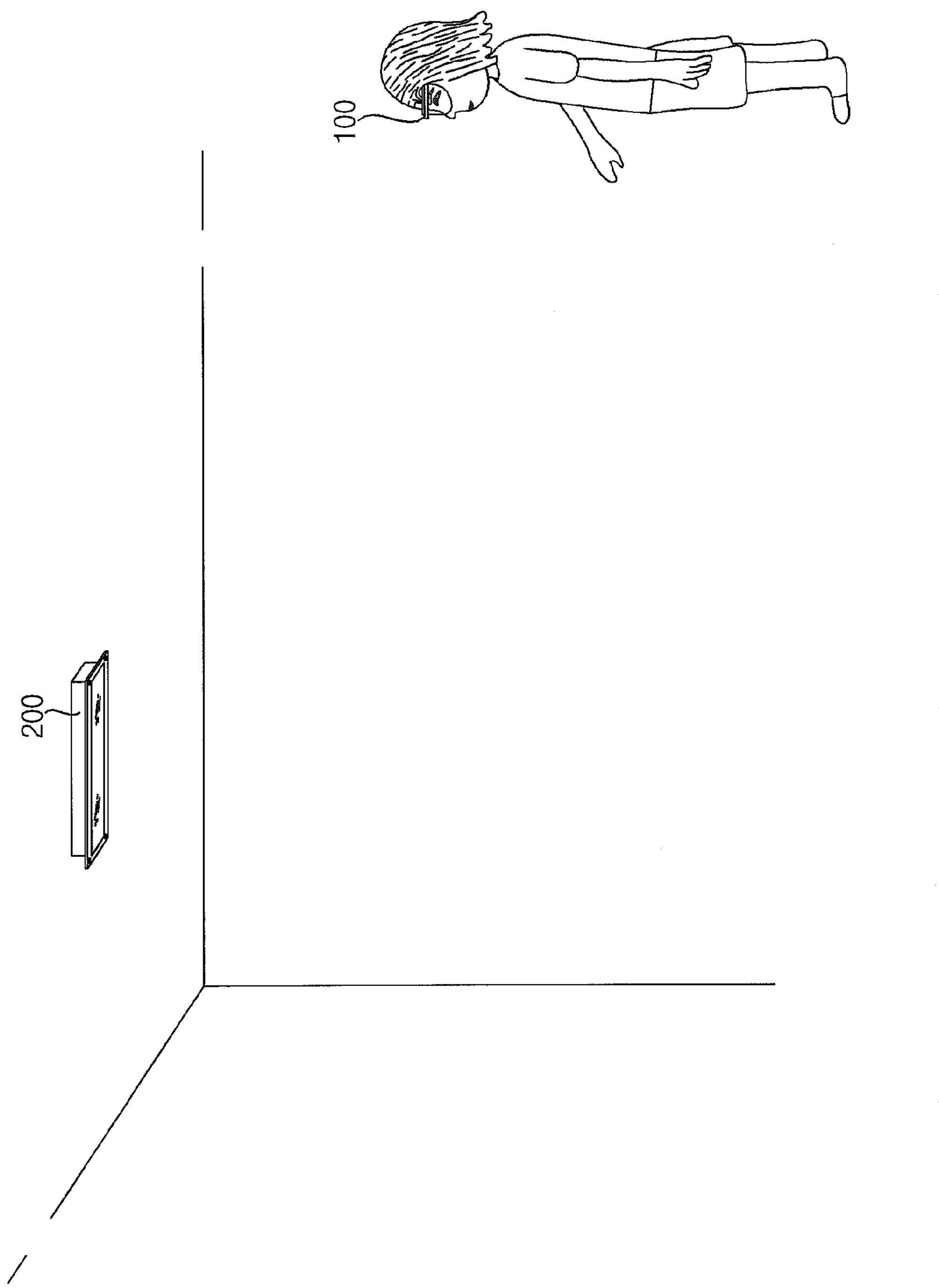


FIG. 1A

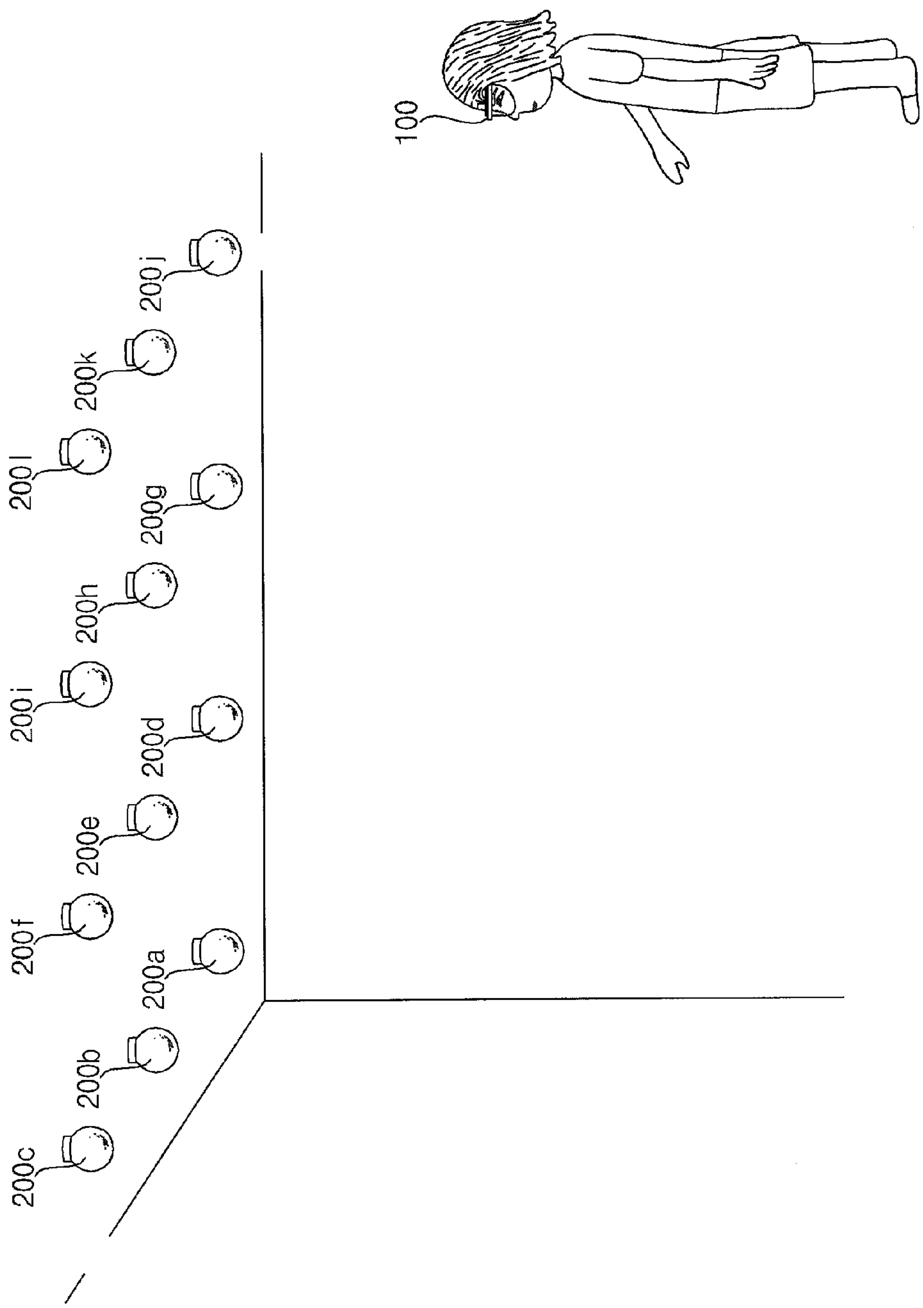

100
200j
200k
200l
200g
200h
200i
200d
200e
200f
200a
200b
200c

FIG. 1B

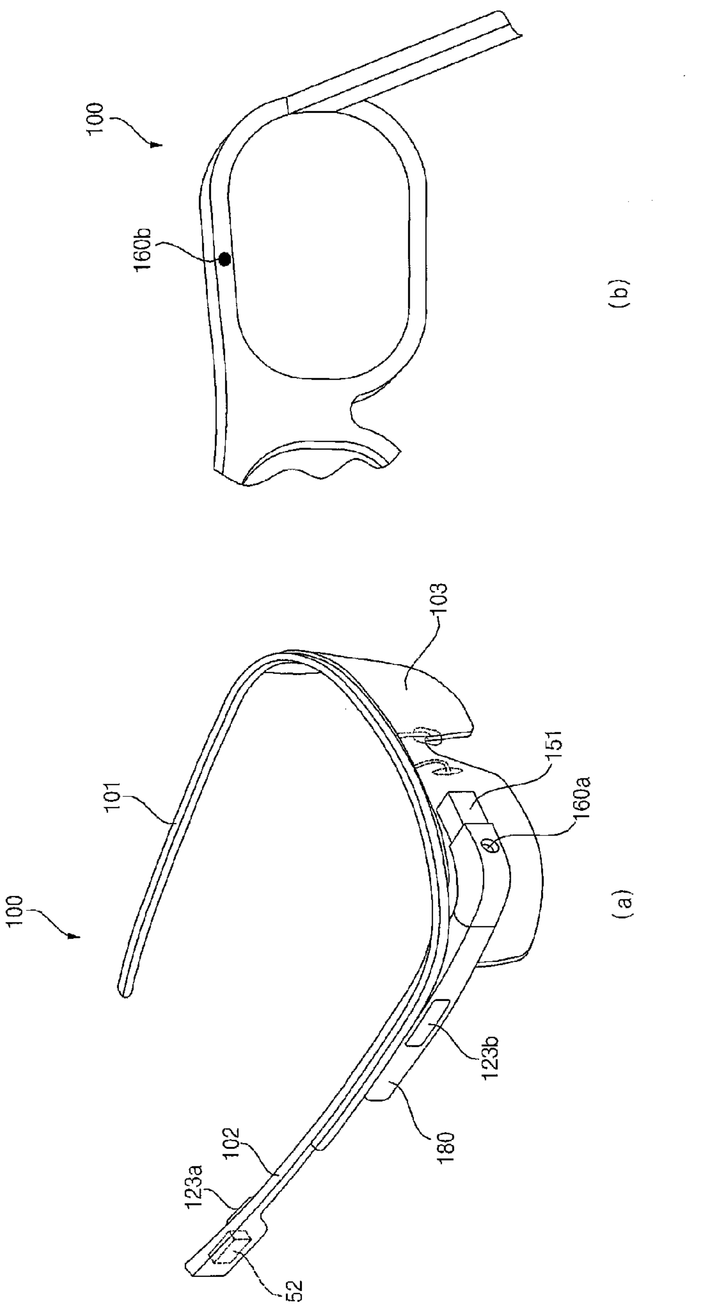


FIG. 2

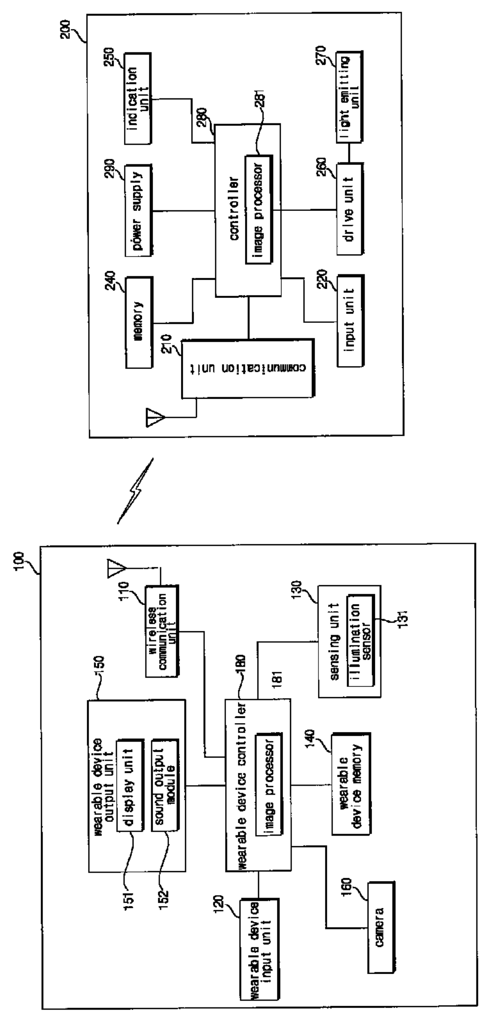
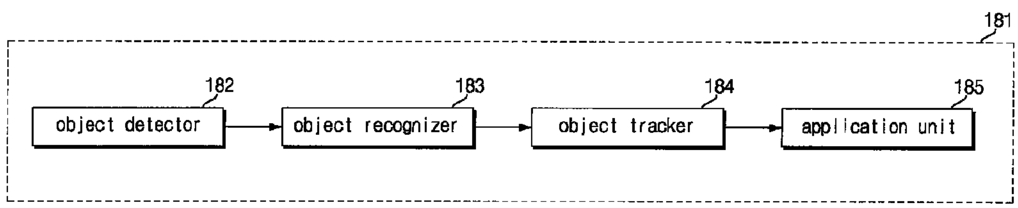
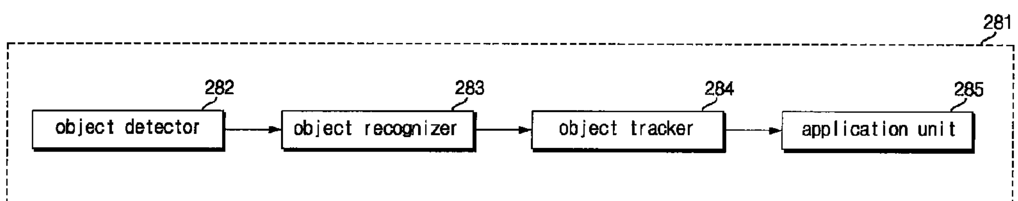

200
250
indication unit
290
power supply
240
memory
210
communication unit
220
input unit
280
controller
281
image processor
260
drive unit
270
light emitting unit
100
110
wireless communication unit
150
wearable device output unit
151
display unit
152
sound output module
180
wearable device controller
181
image processor
130
sensing unit
131
illumination sensor
140
wearable device memory
120
wearable device input unit
160
camera

FIG. 3

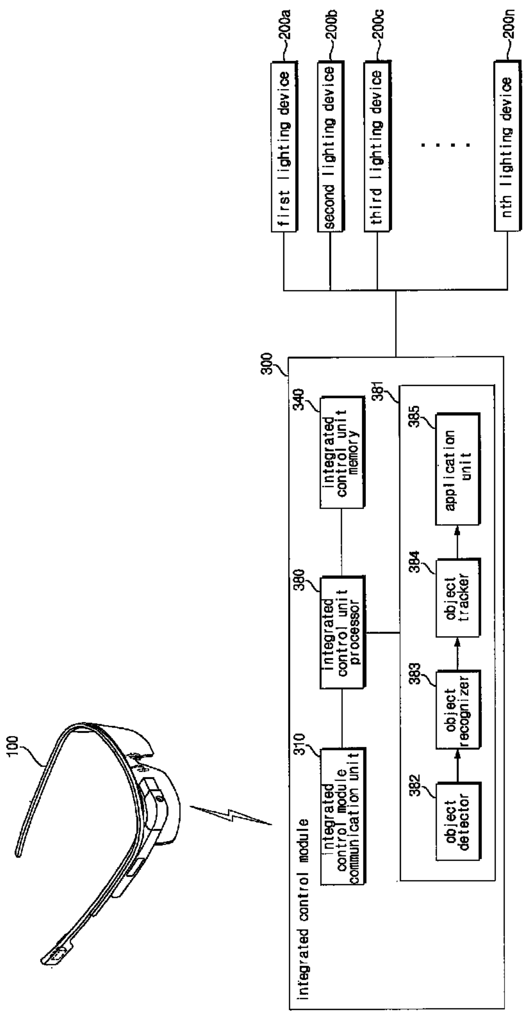
FIG. 4


181
182
object detector
183
object recognizer
184
object tracker
185
application unit

(a)


281
282
object detector
283
object recognizer
284
object tracker
285
application unit

(b)



100
integrated control module
300
310
integrated control module communication unit
380
integrated control unit processor
340
integrated control unit memory
381
382
object detector
383
object recognizer
384
object tracker
385
application unit
first lighting device
200a
second lighting device
200b
third lighting device
200c
nth lighting device
200n

FIG. 5

FIG. 6a

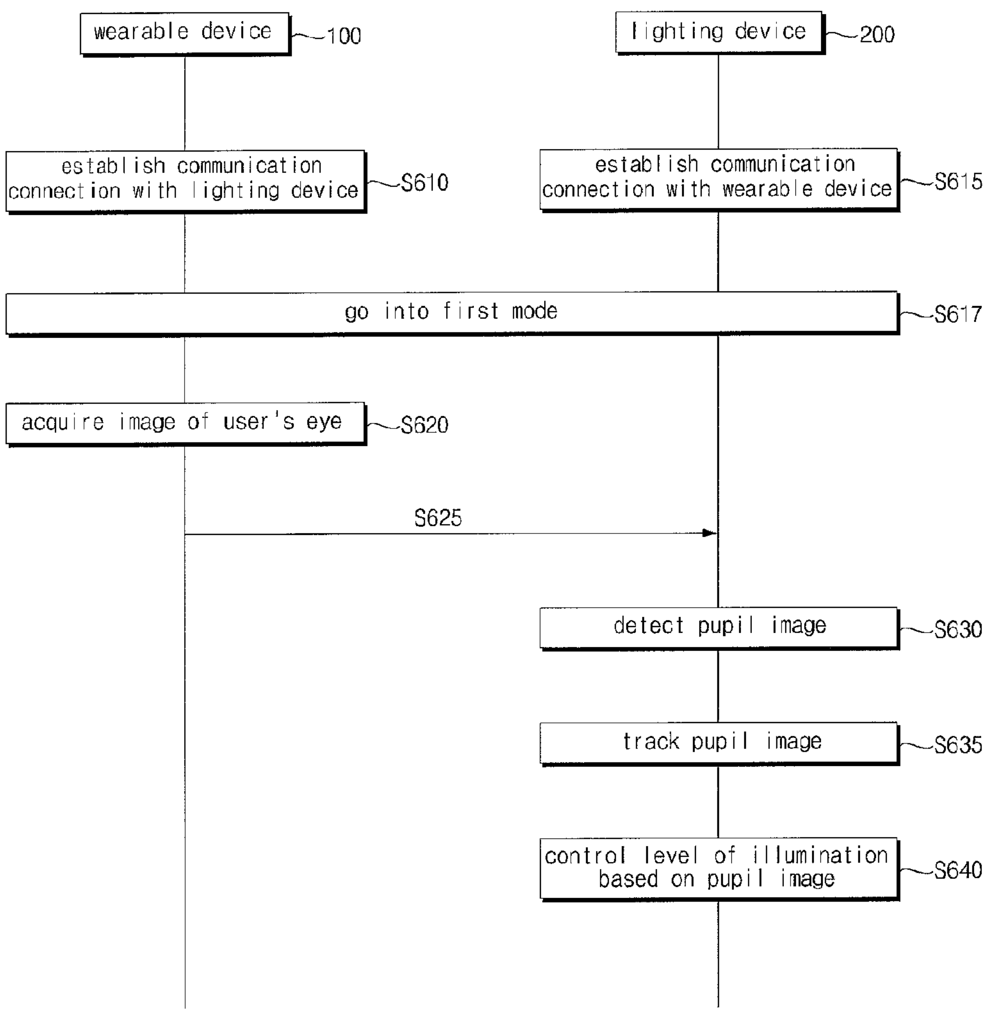
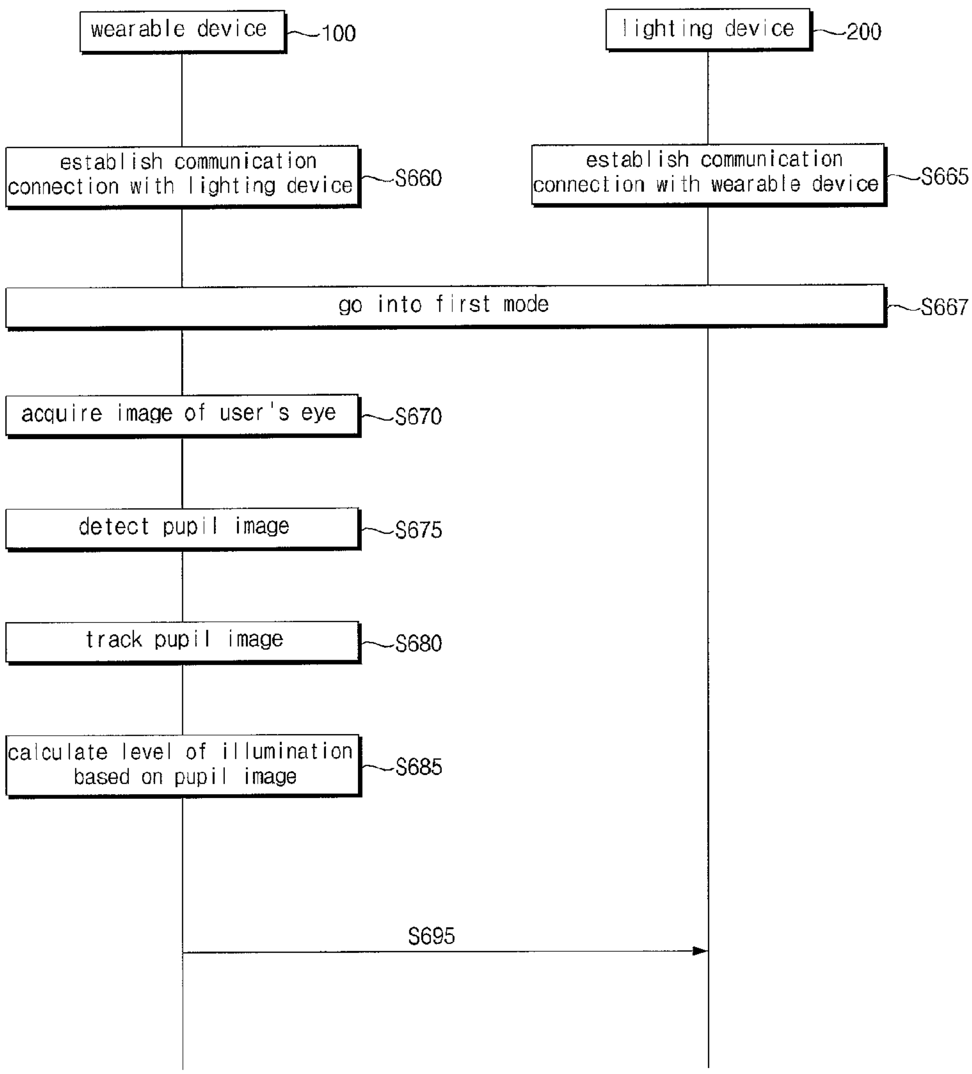

wearable device
100
lighting device
200
establish communication connection with lighting device
S610
establish communication connection with wearable device
S615
go into first mode
S617
acquire image of user's eye
S620
S625
detect pupil image
S630
track pupil image
S635
control level of illumination based on pupil image
S640

FIG. 6b



wearable device
100
lighting device
200
establish communication connection with lighting device
S660
establish communication connection with wearable device
S665
go into first mode
S667
acquire image of user's eye
S670
detect pupil image
S675
track pupil image
S680
calculate level of illumination based on pupil image
S685
S695

FIG. 7a

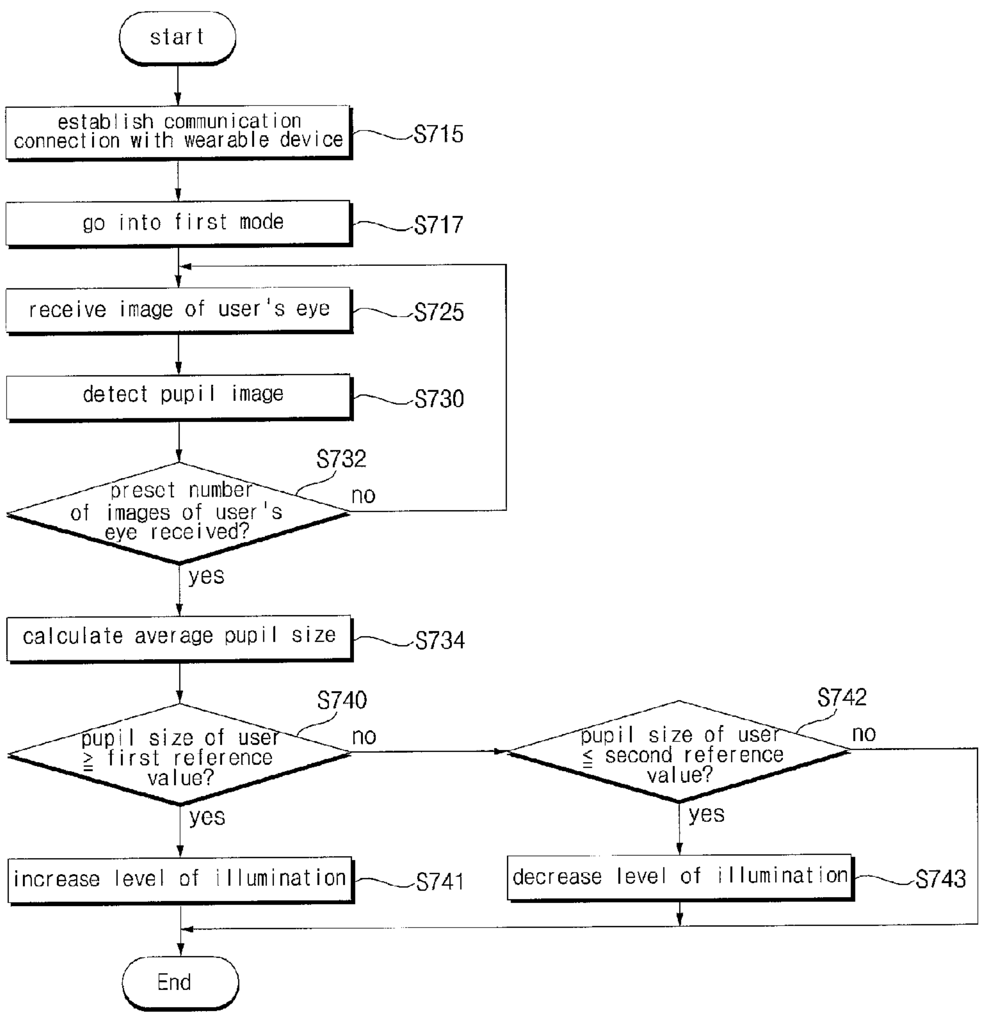
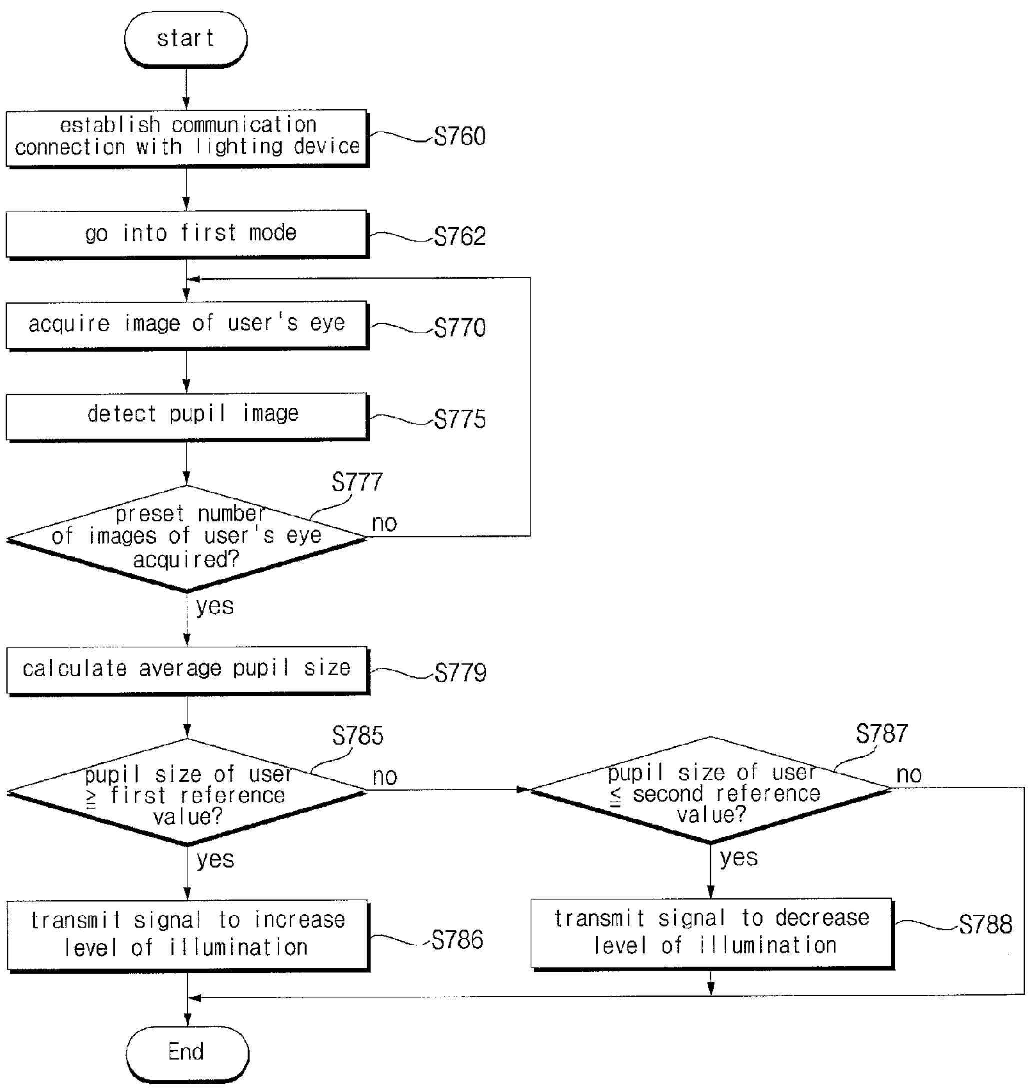

start
establish communication connection with wearable device
S715
go into first mode
S717
receive image of user's eye
S725
detect pupil image
S730
S732
preset number of images of user's eye received?
no
yes
calculate average pupil size
S734
S740
pupil size of user ≧ first reference value?
no
yes
S742
pupil size of user ≤ second reference value?
no
yes
increase level of illumination
S741
decrease level of illumination
S743
End

FIG. 7b



start
establish communication connection with lighting device
S760
go into first mode
S762
acquire image of user's eye
S770
detect pupil image
S775
S777
preset number of images of user's eye acquired?
no
yes
calculate average pupil size
S779
S785
pupil size of user ≥ first reference value?
no
yes
S787
pupil size of user ≤ second reference value?
no
yes
transmit signal to increase level of illumination
S786
transmit signal to decrease level of illumination
S788
End

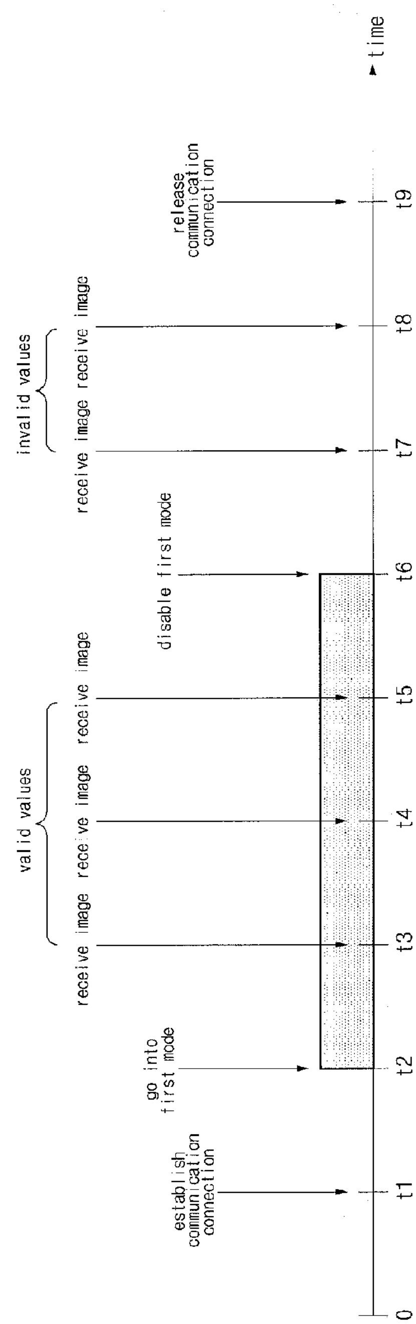

establish communication connection
go into first mode
receive image
receive image
receive image
valid values
disable first mode
receive image
receive image
invalid values
release communication connection
time
0
t1
t2
t3
t4
t5
t6
t7
t8
t9

FIG. 8

FIG. 9

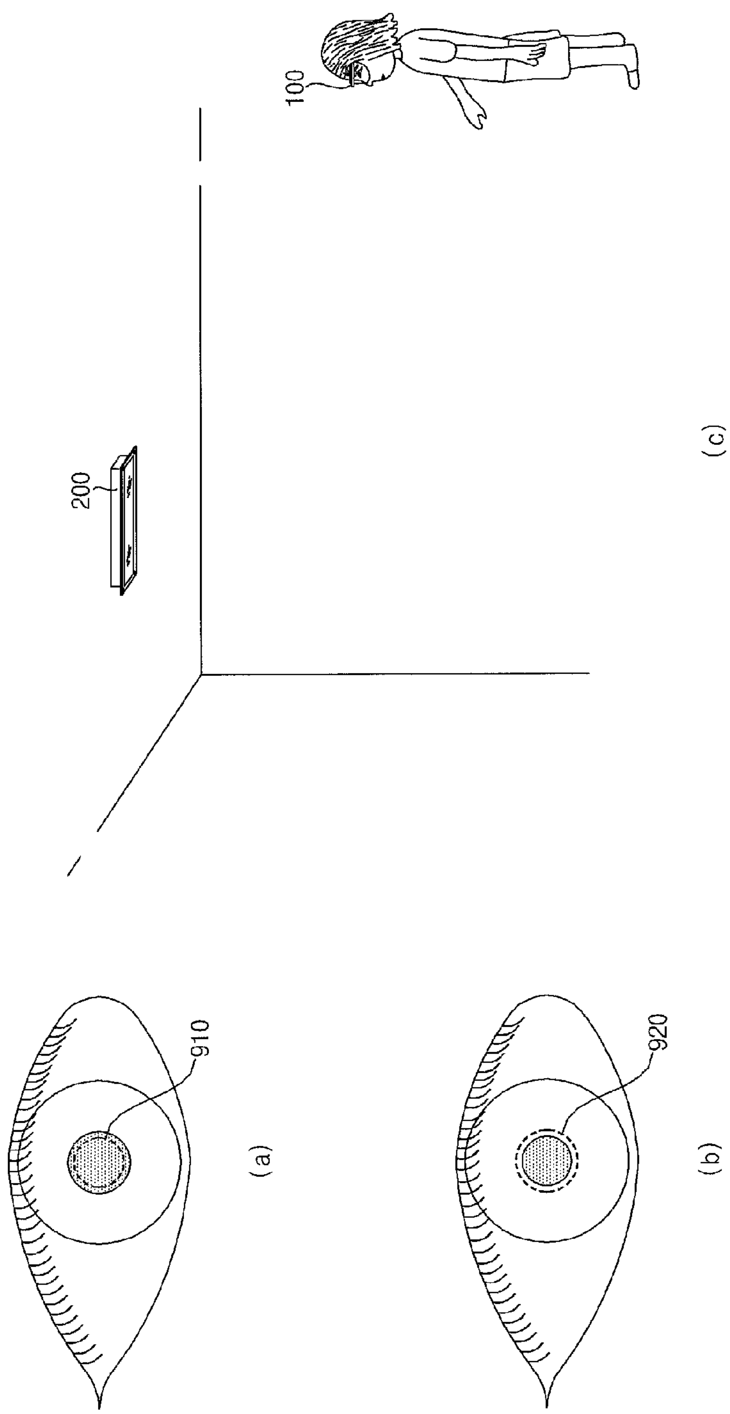


FIG. 10a

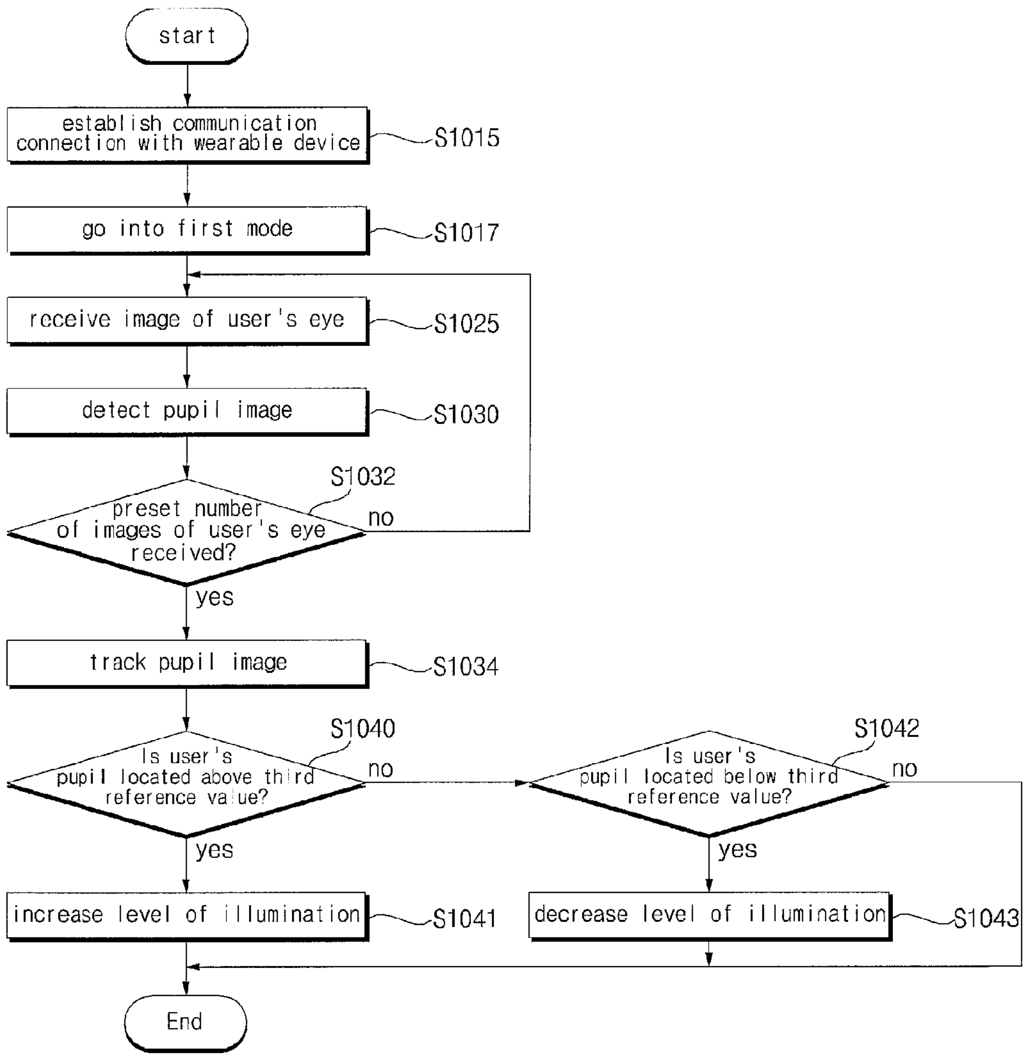
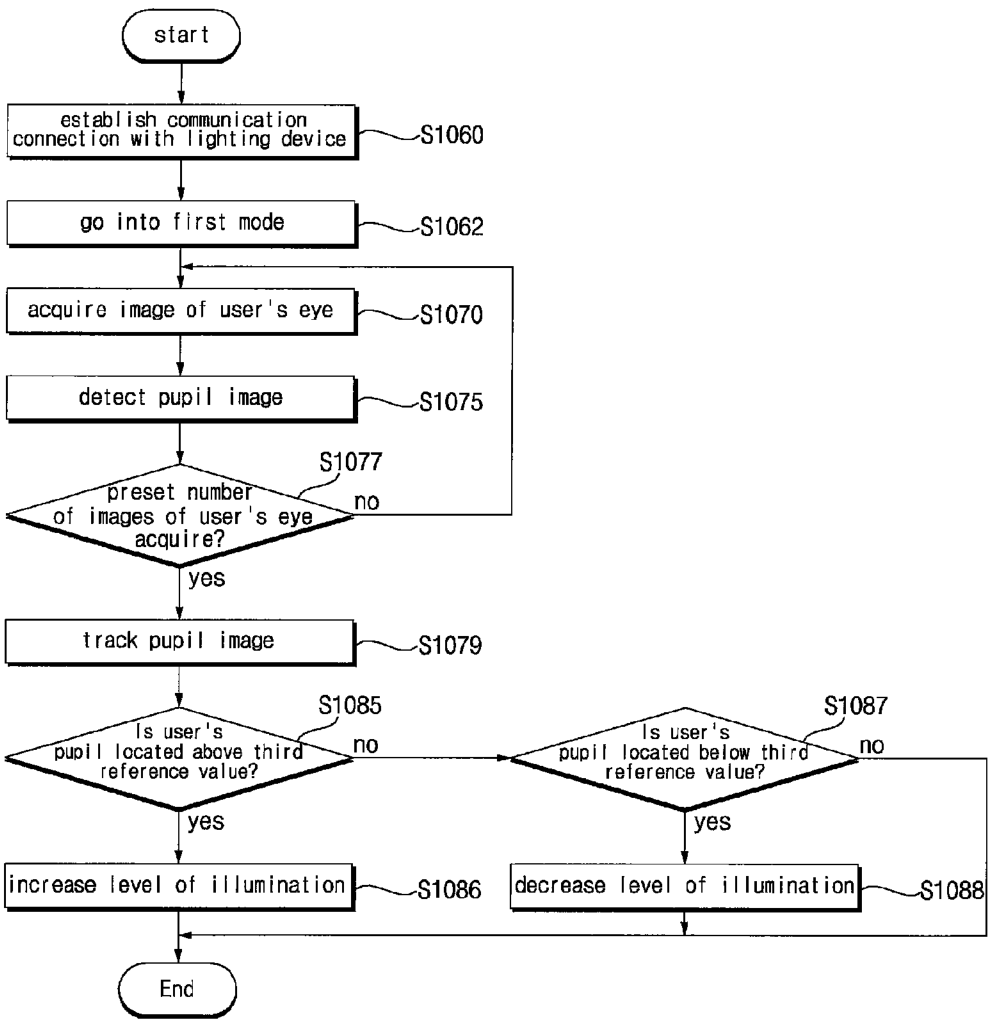

start
establish communication connection with wearable device
S1015
go into first mode
S1017
receive image of user's eye
S1025
detect pupil image
S1030
S1032
preset number of images of user's eye received?
no
yes
track pupil image
S1034
S1040
Is user's pupil located above third reference value?
no
yes
S1042
Is user's pupil located below third reference value?
no
yes
increase level of illumination
S1041
decrease level of illumination
S1043
End

FIG. 10b


start
establish communication connection with lighting device
S1060
go into first mode
S1062
acquire image of user's eye
S1070
detect pupil image
S1075
S1077
preset number of images of user's eye acquire?
no
yes
track pupil image
S1079
S1085
Is user's pupil located above third reference value?
no
yes
S1087
Is user's pupil located below third reference value?
no
yes
increase level of illumination
S1086
decrease level of illumination
S1088
End

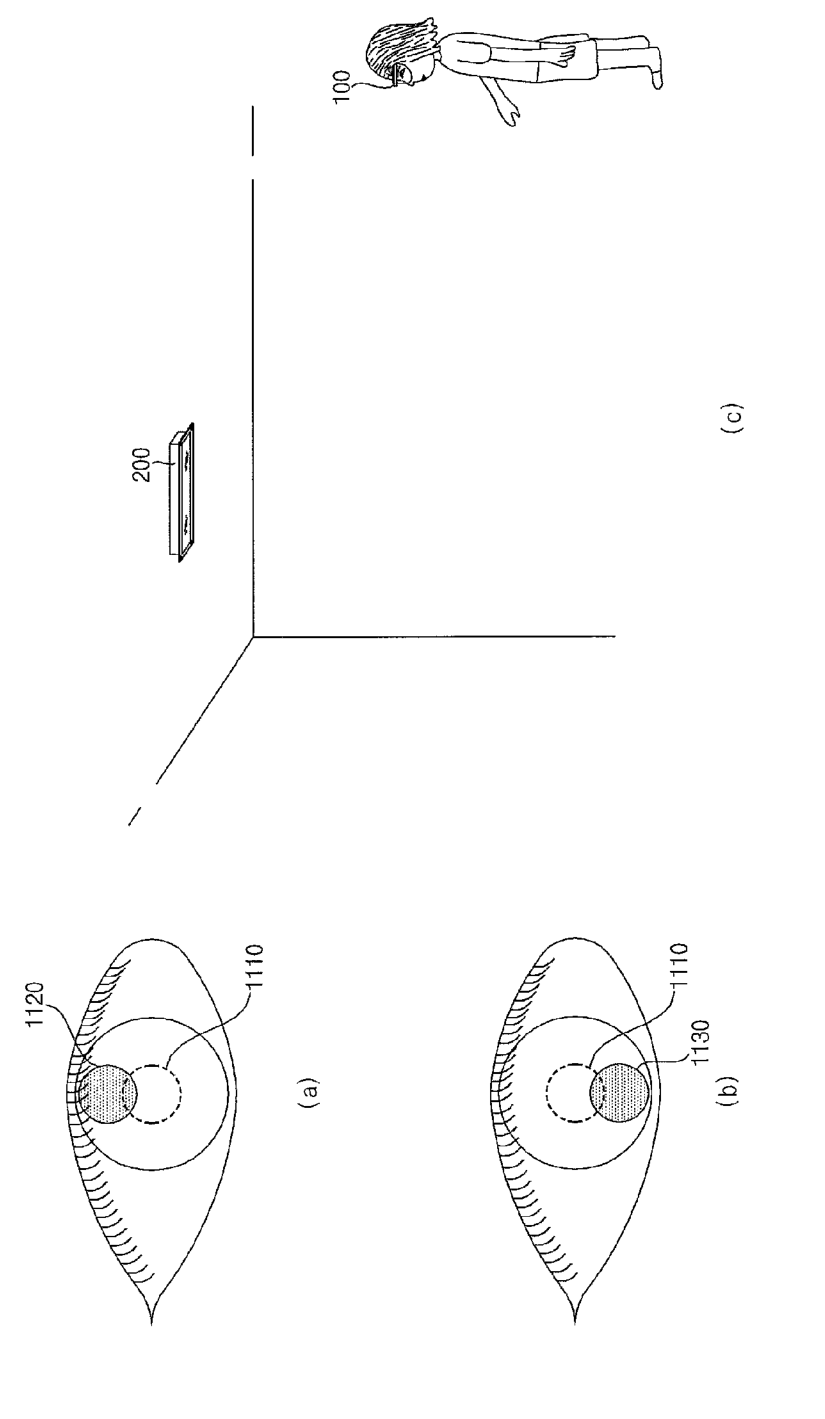


FIG. 11

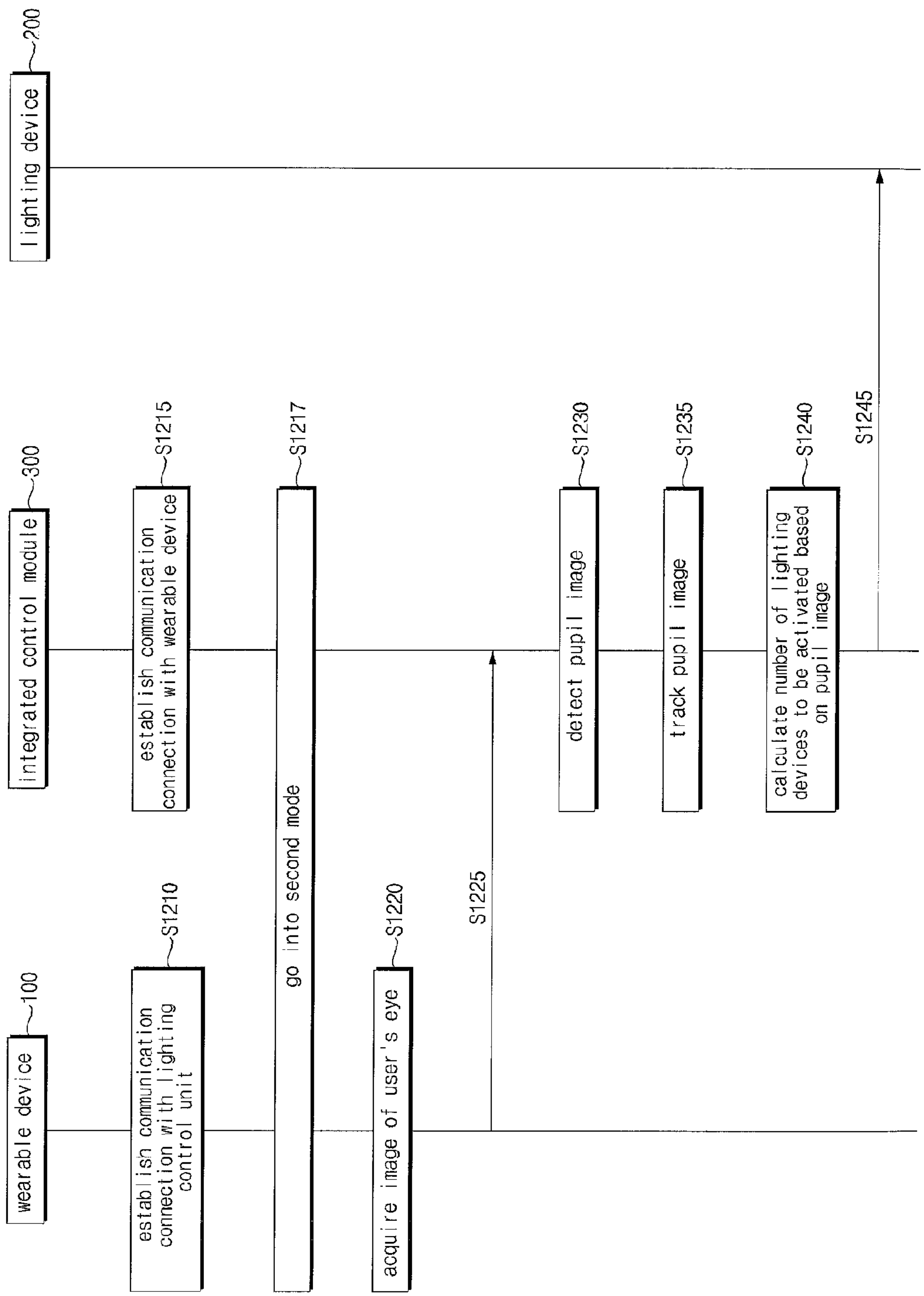
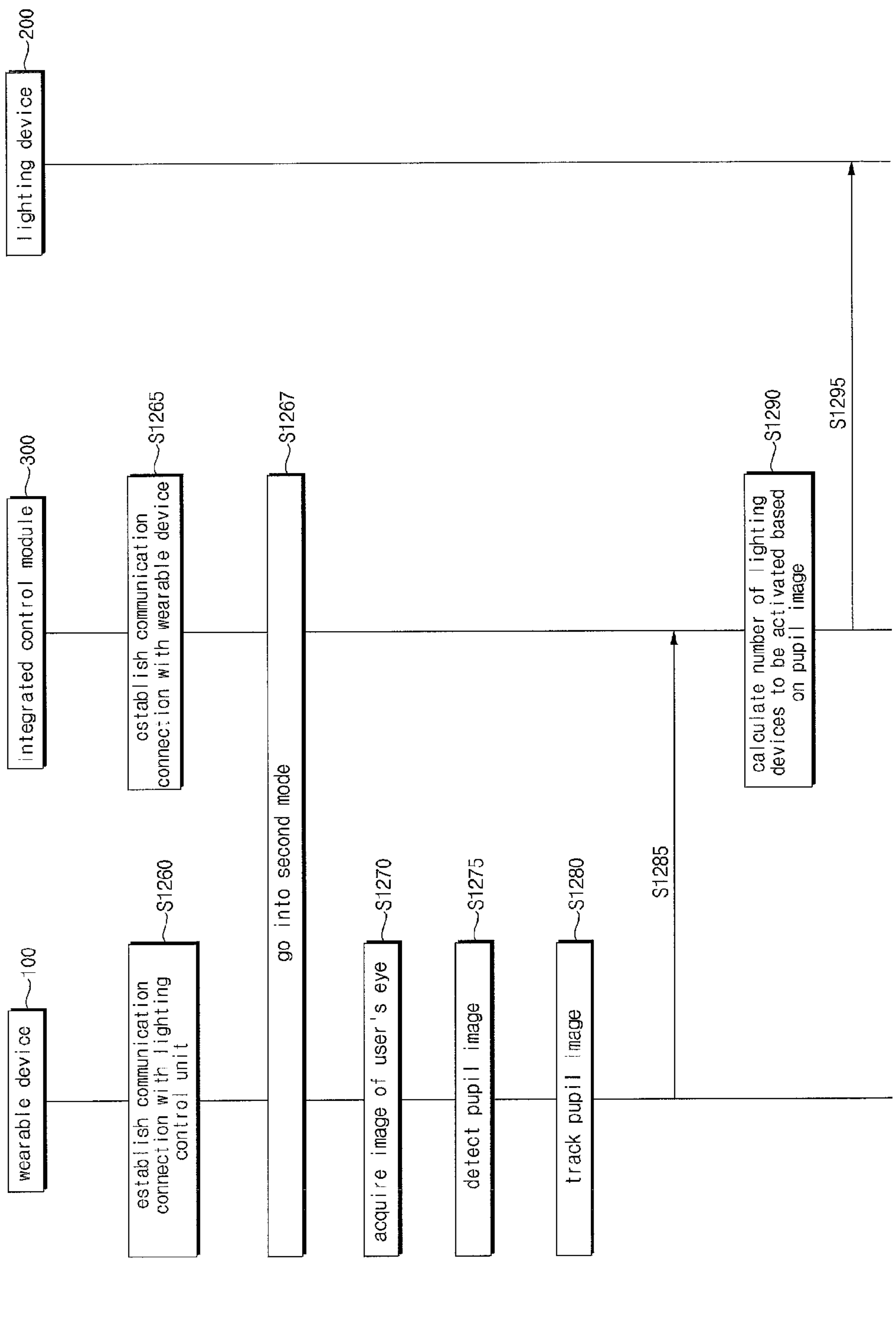

wearable device
100
integrated control module
300
lighting device
200
establish communication connection with lighting control unit
S1210
establish communication connection with wearable device
S1215
go into second mode
S1217
acquire image of user's eye
S1220
S1225
detect pupil image
S1230
track pupil image
S1235
calculate number of lighting devices to be activated based on pupil image
S1240
S1245

FIG. 12a

FIG. 12b



lighting device
200
integrated control module
300
wearable device
100
establish communication connection with lighting control unit
S1260
establish communication connection with wearable device
S1265
go into second mode
S1267
acquire image of user's eye
S1270
detect pupil image
S1275
track pupil image
S1280
S1285
calculate number of lighting devices to be activated based on pupil image
S1290
S1295

FIG. 13a

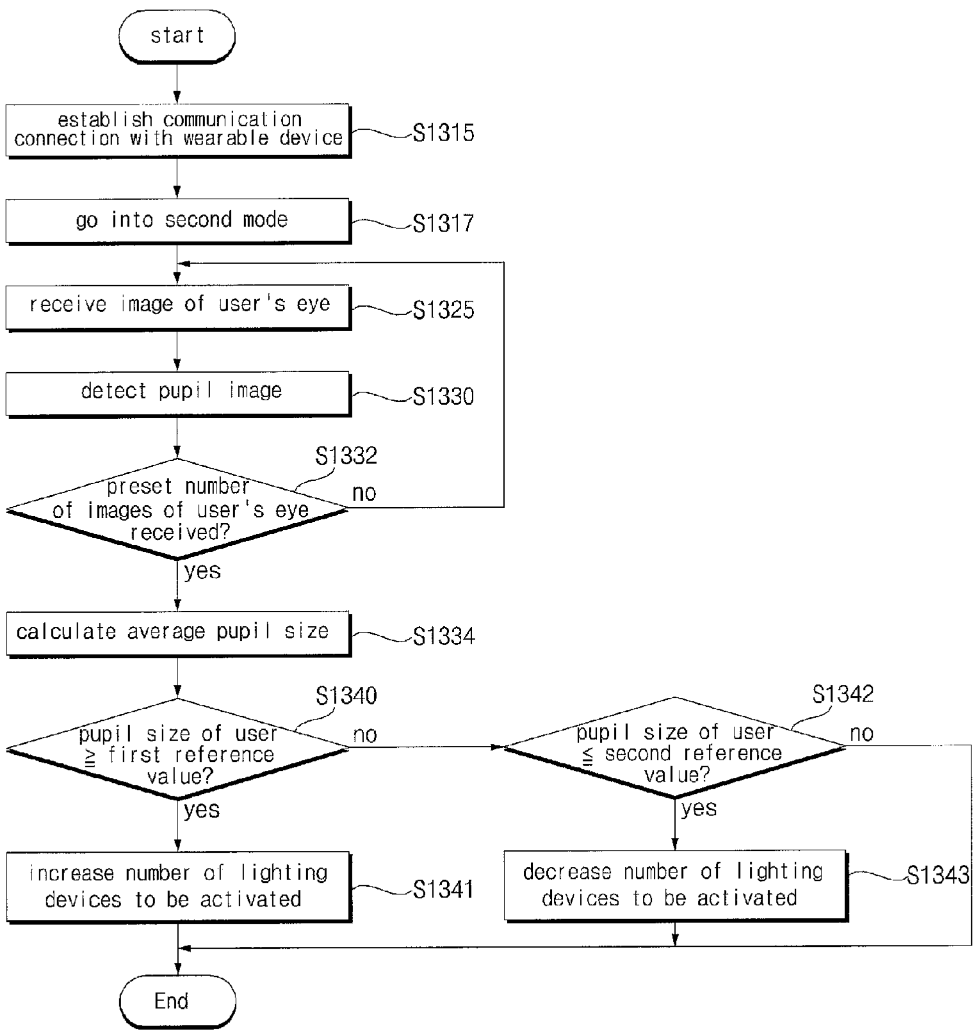

start
establish communication connection with wearable device
S1315
go into second mode
S1317
receive image of user's eye
S1325
detect pupil image
S1330
S1332
preset number of images of user's eye received?
no
yes
calculate average pupil size
S1334
S1340
pupil size of user ≧ first reference value?
no
yes
S1342
pupil size of user ≦ second reference value?
no
yes
increase number of lighting devices to be activated
S1341
decrease number of lighting devices to be activated
S1343
End

FIG. 13b

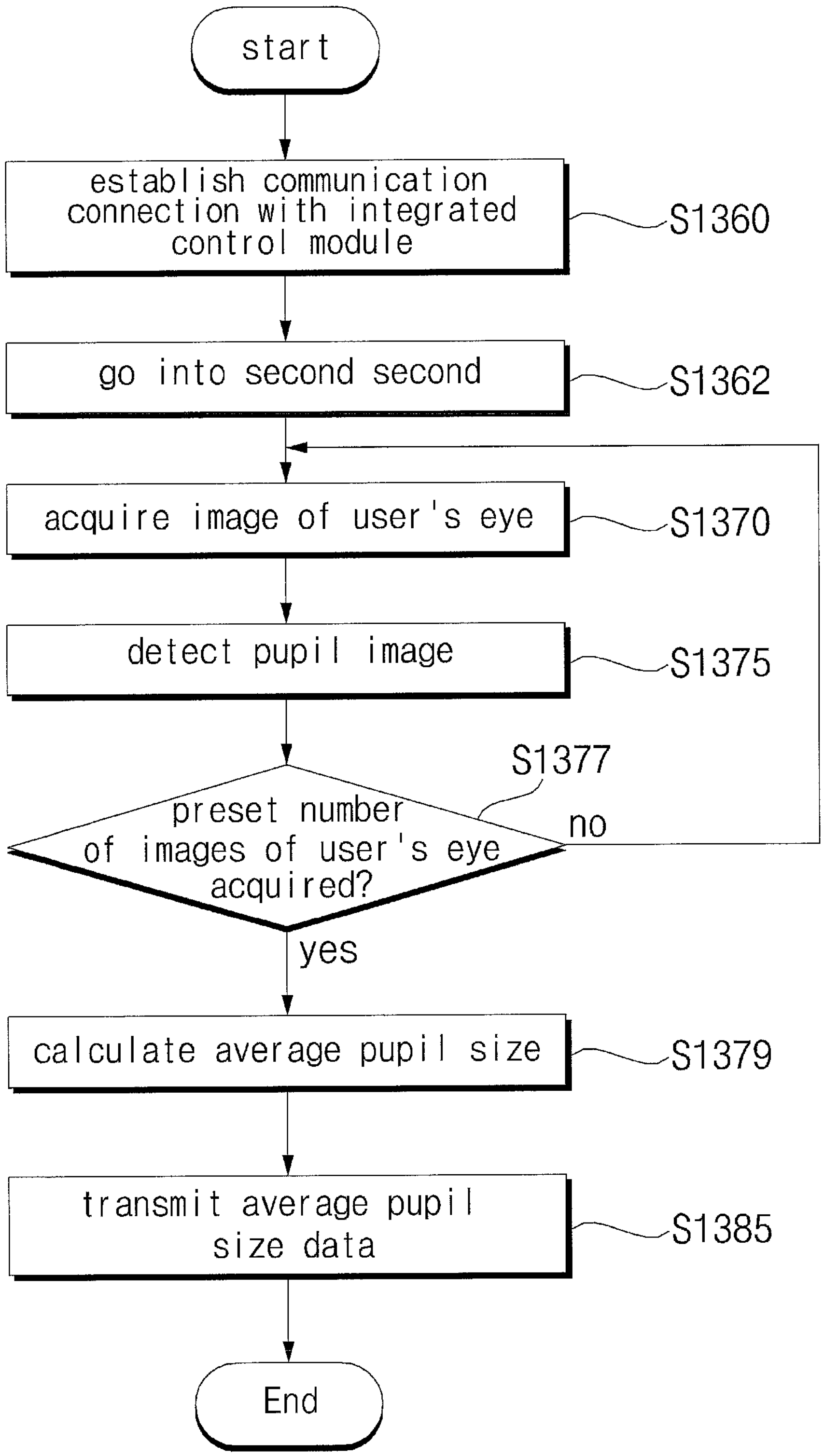

start
establish communication connection with integrated control module
S1360
go into second second
S1362
acquire image of user's eye
S1370
detect pupil image
S1375
S1377
preset number of images of user's eye acquired?
no
yes
calculate average pupil size
S1379
transmit average pupil size data
S1385
End

FIG. 14

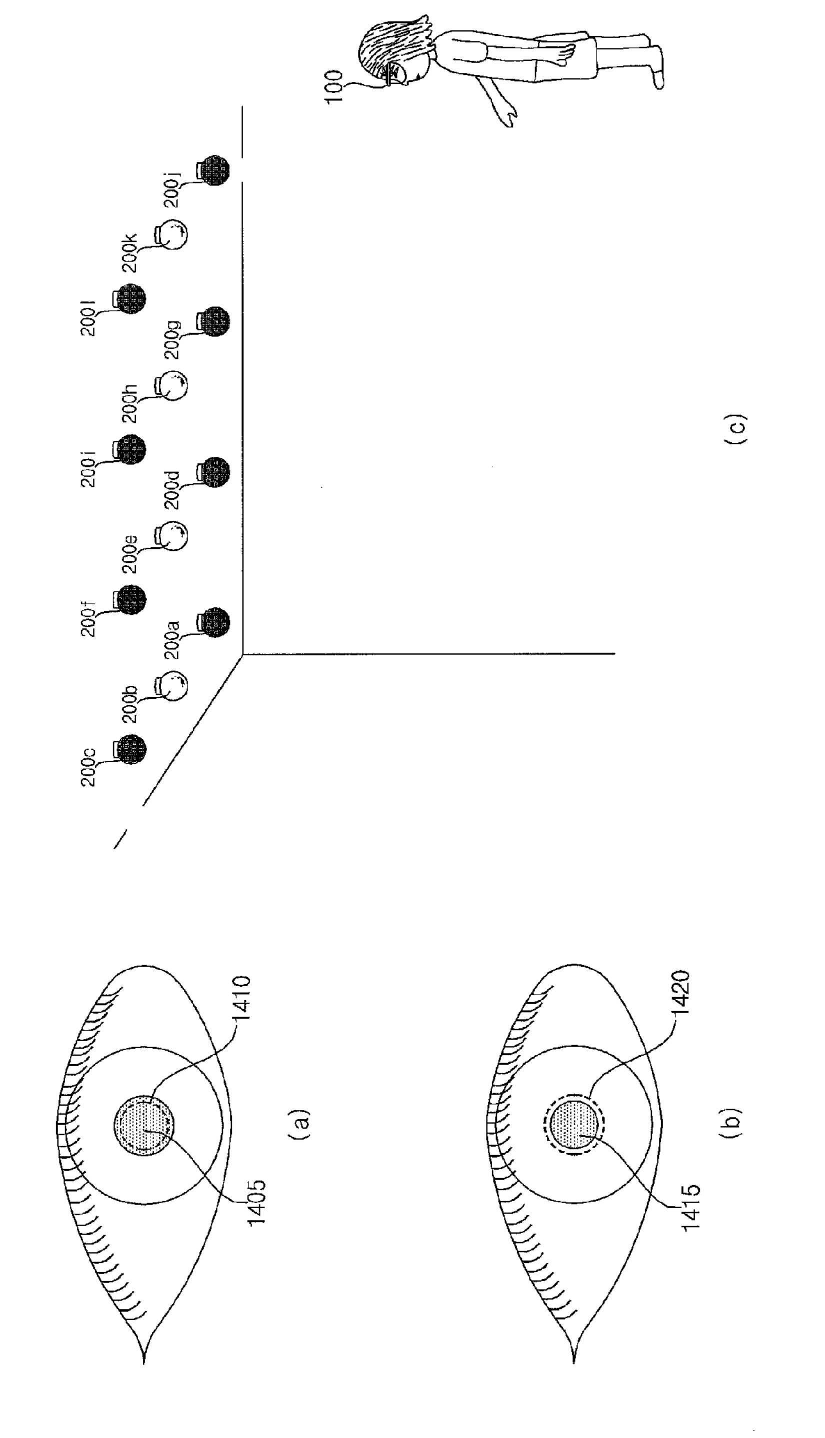

1405
1410
(a)
1415
1420
(b)
100
200a
200b
200c
200d
200e
200f
200g
200h
200i
200j
200k
200l
(c)

FIG. 15a

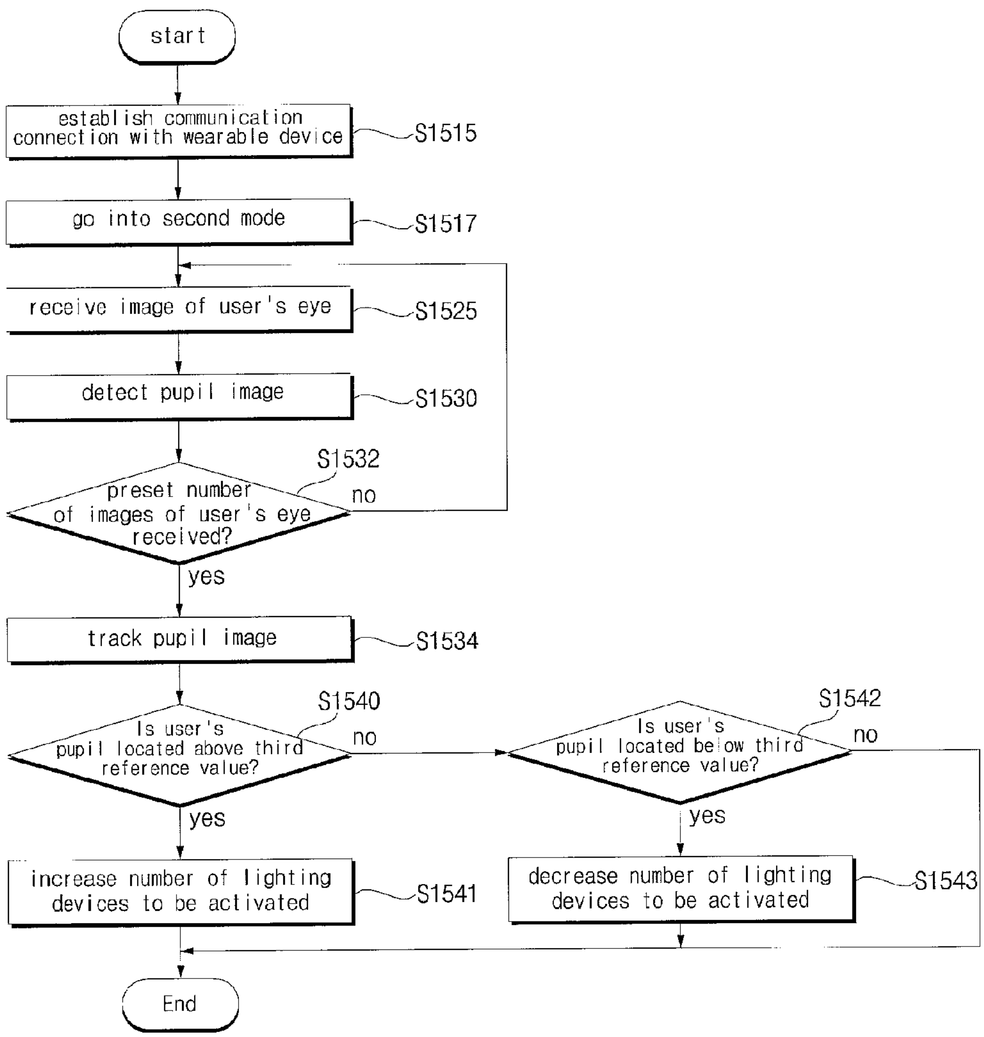
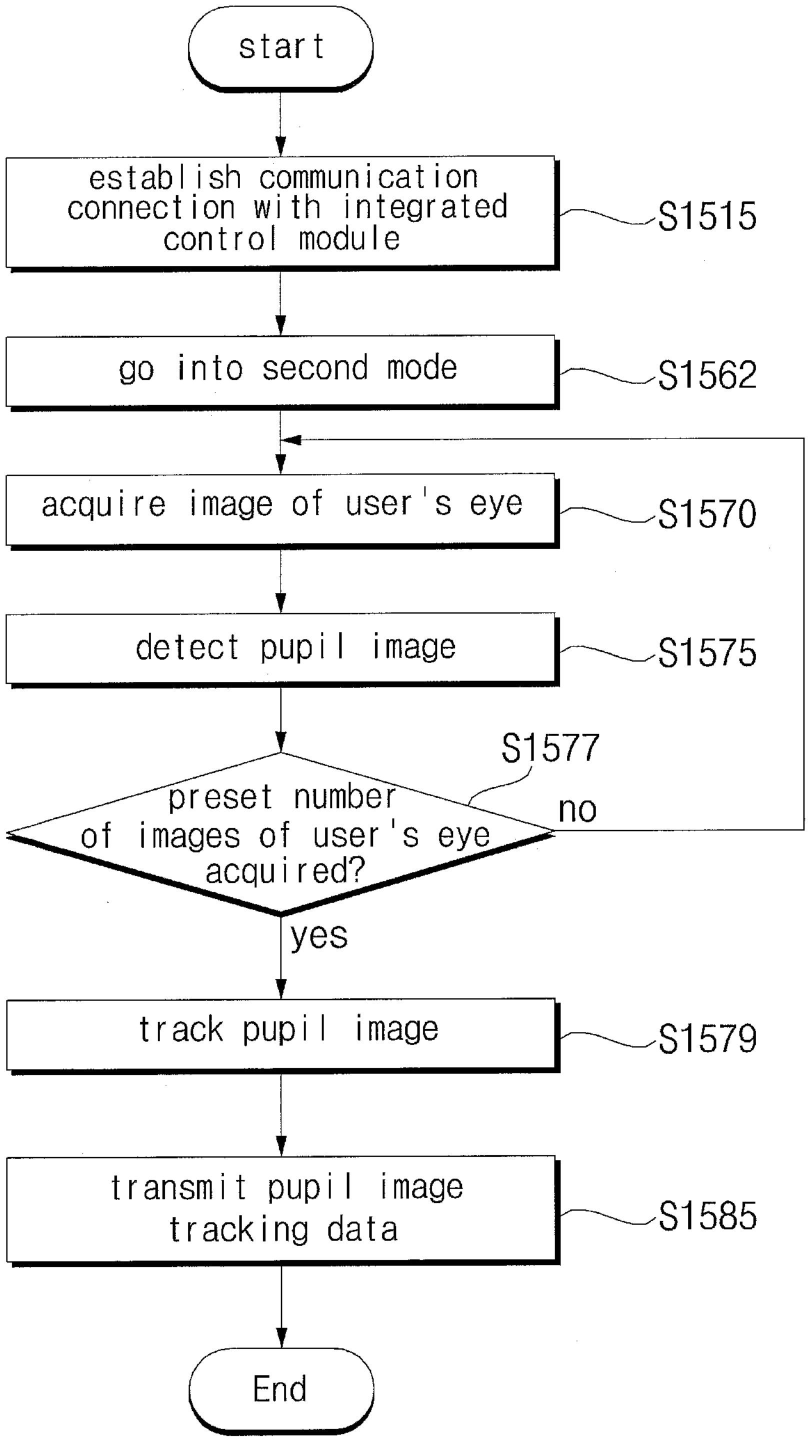

start
establish communication connection with wearable device
S1515
go into second mode
S1517
receive image of user's eye
S1525
detect pupil image
S1530
S1532
preset number of images of user's eye received?
no
yes
track pupil image
S1534
S1540
Is user's pupil located above third reference value?
no
yes
S1542
Is user's pupil located below third reference value?
no
yes
increase number of lighting devices to be activated
S1541
decrease number of lighting devices to be activated
S1543
End

FIG. 15b


start
establish communication connection with integrated control module
S1515
go into second mode
S1562
acquire image of user's eye
S1570
detect pupil image
S1575
S1577
preset number of images of user's eye acquired?
no
yes
track pupil image
S1579
transmit pupil image tracking data
S1585
End

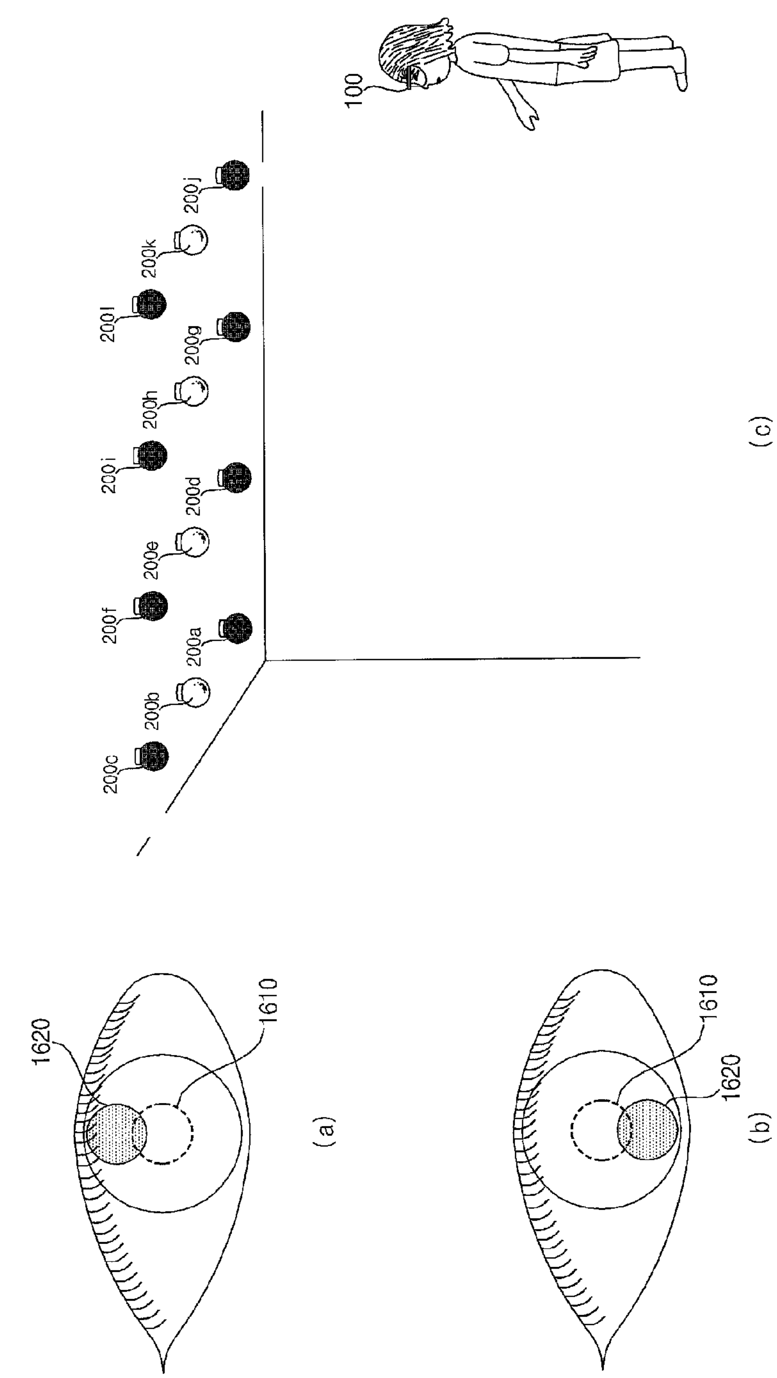
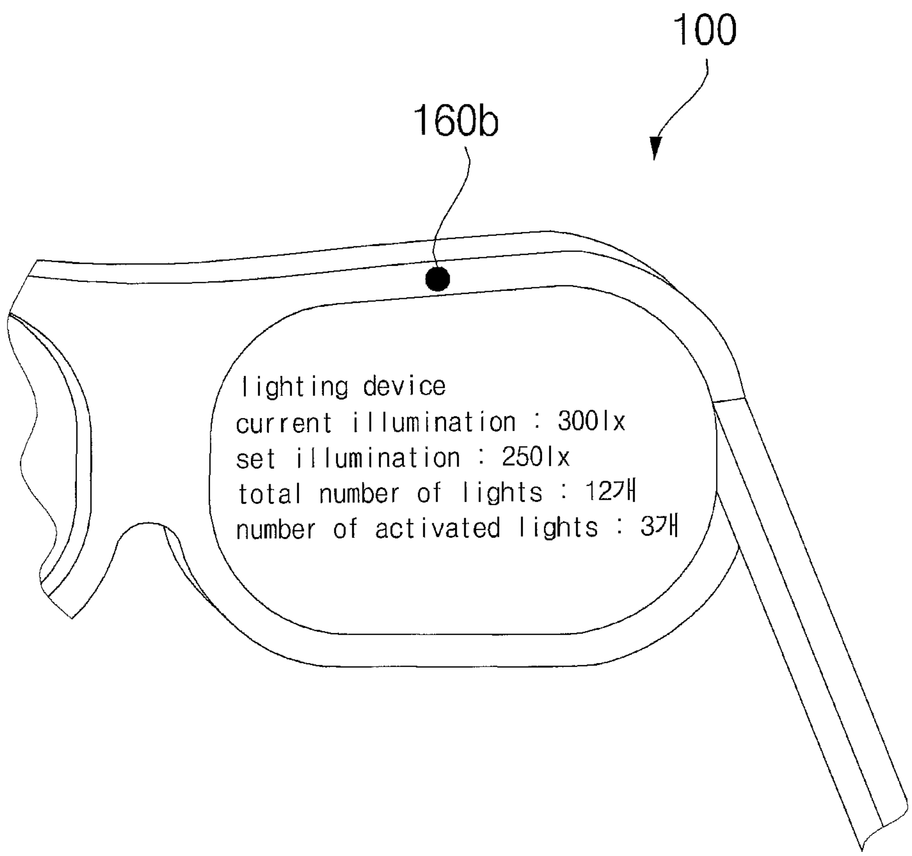

100
200j
200k
200l
200g
200h
200i
200d
200e
200f
200a
200b
200c
(c)
1620
1610
(a)
1610
1620
(b)

FIG. 16

FIG. 17


100
160b
lighting device
current illumination : 300lx
set illumination : 250lx
total number of lights : 12개
number of activated lights : 3개

LIGHTING DEVICE, LIGHTING SYSTEM AND WEARABLE DEVICE HAVING IMAGE PROCESSOR

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority under 35 U.S.C. §119 to Korean Application No. 10-2014-0053488 filed on May 2, 2014, whose entire disclosure is hereby incorporated by reference.

BACKGROUND

1. Field

The present invention relates to a lighting system and a control method thereof which allow for lighting control based on images of a user's eye.

2. Background

The lighting industry has continued to grow over the years. A lot of research on light sources, light emission methods, operation methods, efficiency improvement is under way in connection with the lighting industry.

Light sources currently used mainly for illumination include incandescent lamps, discharge lamps, and fluorescent lamps. Lighting using these light sources is used for various purposes such as home lighting, landscape lighting, industrial lighting, etc. Resistant light sources, such as the incandescent lamps, may have the problems of poor efficiency and heat generation. The discharge lamps may have the problems of high price and high voltage. The fluorescent lamps may have environmental problems caused by the use of mercury.

There is growing interest in light emitting diode (LED) lighting to solve the drawbacks of light sources. The LED lighting has advantages in efficiency, color variability, design flexibility, etc.

The light emitting diode is a semiconductor device that emits light when a voltage is applied thereto in a forward direction. The light emitting diode may have long lifetime, low power consumption, and electric, optical and physical characteristics suitable for mass production, to rapidly replace incandescent lamps and fluorescent lamps.

Smart technologies are getting attention recently which provide a domestic ubiquitous environment where computing can occur anytime, in any place, and on any device by employing home networking and internet information home appliances based on wired/wireless communications and digital information appliances.

By combining smart technologies with lighting, technical advancements have been made in lighting control with a terminal when the lighting and the terminal are connected for communication. However, the user has to enter a command on the terminal to control the lighting using the terminal.

BRIEF DESCRIPTION OF THE DRAWINGS

The embodiments will be described in detail with reference to the following drawings in which like reference numerals refer to like elements wherein:

FIGS. **1***a* and **1***b* are views showing an environment where a lighting system according to an exemplary embodiment of the present invention is used;

FIG. **2** is a view showing the wearable device according to the exemplary embodiment of the present invention;

FIG. **3** is a block diagram showing the components of the lighting system according to the exemplary embodiment of the present invention;

FIG. **4** is a block diagram showing the components of an image processor according to the exemplary embodiment of the present invention;

FIG. **5** is a block diagram showing the components of the lighting system according to the exemplary embodiment of the present invention;

FIGS. **6***a* and **6***b* are signal-flow charts of a lighting system according to a first or second exemplary embodiment of the present invention;

FIGS. **7***a* and **7***b* are flowcharts illustrating the operation of the lighting system according to the first exemplary embodiment of the present invention;

FIG. **8** is a view referenced to describe the operation of receiving an image in the first mode according to an exemplary embodiment of the present invention;

FIG. **9** is an illustration of the operation of the lighting system according to the first exemplary embodiment of the present invention;

FIGS. **10***a* and **10***b* are signal-flow charts of the lighting system according to the second exemplary embodiment of the present invention;

FIG. **11** is an illustration of the operation of the lighting system according to the second exemplary embodiment of the present invention;

FIGS. **12***a* and **12***b* are signal-flow charts of a lighting system according to a third or fourth exemplary embodiment of the present invention;

FIGS. **13***a* and **13***b* are signal-flow charts of the lighting system according to the third exemplary embodiment of the present invention;

FIG. **14** is an illustration of the operation of the lighting system according to the third exemplary embodiment of the present invention;

FIGS. **15***a* and **15***b* are signal-flow charts of the lighting system according to the fourth exemplary embodiment of the present invention;

FIG. **16** is an illustration of the operation of the lighting system according to the fourth exemplary embodiment of the present invention; and

FIG. **17** is an illustration of a lighting control screen displayed on a wearable device according to an exemplary embodiment of the present invention.

DETAILED DESCRIPTION

Hereinafter the present invention will be described in detail with reference to the accompanying drawings.

In the following description, usage of suffixes such as 'module', 'unit' or 'unit' used for referring to elements is given merely to facilitate explanation of the present disclosure, without having any significant meaning by itself. Accordingly, both 'module' and 'unit' can be used in combination.

This specification will be described, focusing on, but not limited to, a glasses-type wearable device **100**. The wearable device **100** refers to an electronic device that can be worn.

FIGS. **1***a* and **1***b* are views showing an environment where a lighting system according to an exemplary embodiment of the present invention is used.

Referring to FIG. **1***a*, a lighting system according to a first or second exemplary embodiment of the present invention includes a wearable device **100** and a lighting device **200**.

The wearable device **100** has at least one camera. The wearable device **100** captures an image of an eye of a user wearing the wearable device **100**. The wearable device **100** communicates with the lighting device **200**. The wearable device **100** transmits the image of the user's eye to the lighting device **200**.

The lighting device **200** communicates with the wearable device **100**. The lighting device **200** receives the image of the user's eye from the wearable device **100**. The lighting device **200** controls the level of illumination based on the received image of the user's eye.

Referring to FIG. **1***b*, a lighting system according to a third or fourth exemplary embodiment of the present invention includes a wearable device **100**, an integrated control module, and a plurality of lighting devices **200** (**200***a* to **200***l*). It should be made clear that FIG. **1***b* illustrates, but is not limited to, twelve lighting devices.

The wearable device **100** has at least one camera. The wearable device **100** captures an image of an eye of a user wearing the wearable device **100**. The wearable device **100** communicates with the integrated control module. The wearable device **100** transmits the image of the user's eye to the integrated control module.

The integrated control module communicates with the wearable device **100**. The integrated control module receives the image of the user's eye from the wearable device **100**. The integrated control module controls the number of lighting devices **200** (**200***a* to **200***l*) to be activated, based on the received image of the user's eye.

FIG. **2** is a view showing the wearable device according to the exemplary embodiment of the present invention.

Referring to FIG. **2**, the glasses-type wearable device **100** is configured to be worn on a human head. To this end, a frame unit (a case, a housing, etc.) may be provided. The frame unit may be formed of a flexible material to make it easy to wear. This figure illustrates that the frame unit includes a first frame **101** and a second frame **102** that are made of different materials.

The frame unit is supported on the head, and has a space where various components are mounted. As shown therein, electronic components such as a wearable device controller **180** and a sound output module **152** may be mounted on the frame unit. A lens **103** that covers at least one of the left and right eye regions may be detachably mounted on the frame unit.

The wearable device controller **180** is adapted to control various electronic components in the wearable device **100**. This figure illustrates that the wearable device controller **180** is installed on one side of the frame unit on the head. However, the position of the wearable device controller **180** is not limited to the illustrated position.

The wearable device **100** includes a display unit **151** that receives a control command from the wearable device controller **180** and outputs it to a predetermined screen.

The wearable device **100** includes at least one camera **160**. FIG. **2** illustrates that the wearable device **100** includes a first camera **160***a* and a second camera **160***b*.

This figure illustrates that the first camera **160***a* is provided on the wearable device controller **180** and the second camera **160***b* is provided on the frame unit in proximity to one of the user's eyes; however, the present invention is not limited to this illustrated example.

The glasses-type wearable device **100** may have user input units **123***a* and **123***b* that are manipulated to receive a control command. The user input units **123***a* and **123***b* can employ any method so long as they can be manipulated in a tactile manner like touching, pushing, etc. This figure illustrates that the frame unit and the wearable device controller **180** include push-and-touch type user input units **123***a* and **123***b*, respectively.

Moreover, the glasses-type wearable device **100** may have a microphone (not shown) that receives sound and processing it into electric audio data and a sound output module **152** that outputs sound. The sound output module **152** may be adapted to transmit sound by a typical sound output method or by bone conduction. When implemented by bone conduction, the sound output module **152** of the wearable device **100** worn on the user is tightly attached to the head, and transmits sound by vibrating the skull.

FIG. **3** is a block diagram showing the components of the lighting system according to the exemplary embodiment of the present invention.

Referring to FIG. **3**, the lighting system according to the first or second exemplary embodiment of the present invention may include a wearable device **100** and a lighting device **200**.

The wearable device **100** may include a wireless communication unit **110**, a wearable device input unit **120**, a sensing unit **130**, a wearable device memory **140**, a wearable device output unit **150**, and a wearable device controller **180**.

The wireless communication unit **110** may include one or more modules that enable wireless communications between the wearable device **100** and the lighting device **200** or between the wearable device **100** and the integrated control module **300**. Moreover, the wireless communication unit **110** may include one or more modules that connect the wearable device **100** to one or more communication networks.

The wireless communication unit **110** is able to communicate with the lighting device **200** over Bluetooth. Bluetooth allows for communication at low power and can be set up at low cost. Accordingly, Bluetooth is preferred for indoor short range communication between the wearable device **100** and the lighting device **200**.

The wireless communication unit **110** may use communication protocols such as Wi-Fi Direct, RFID (Radio Frequency Identification), IrDA (Infrared Data Association), UWB (Ultra Wideband), ZigBee, and NFC (Near Field Communication), as well as Bluetooth.

The wireless communication unit **110** communicates with the lighting device **200**, and transmits information sensed by the sensing unit **130** or an image captured by a camera **160** to the lighting device **200**. Alternatively, the wireless communication unit **110** may transmit a control signal for controlling the lighting device **200** according to an exemplary embodiment.

The wearable device input unit **120** may include a camera **160** or image input unit for inputting an image signal, a microphone (not shown) or audio input unit for inputting an audio signal, and a user input unit (not shown, for example, a touch key or a mechanical key) for receiving information from the user. Audio data or image data collected by the wearable device input unit **120** may be analyzed and processed into a user's control command. For example, the wearable device controller **180** may control the wearable device **100** to receive the user's voice through the microphone and go into the first mode. The first mode may be a mode for controlling lighting based on an image of a user's eye (e.g., pupil image) while the wearable device **100** and the lighting device **200** are connected for communication.

The sensing unit **130** may include one or more sensors for sensing at least one of the following: information in the wearable device **100**, information on the environment surrounding the wearable device **100**, and user information.

For example, the sensing unit **130** may include at least one of the following: an illumination sensor **131**, a motion sensor, an optical sensor (e.g., camera), a touch sensor, a proximity sensor, an acceleration sensor, a magnetic sensor, a G-sensor, a gyroscope sensor, an RGB sensor, an IR (infrared) sensor, a finger scan sensor, an ultrasonic sensor, a microphone, a battery gauge, an environment sensor (e.g., barometer, hygrometer, thermometer, radiation sensor, thermal sensor, or gas sensor), and a chemical sensor (e.g., electronic nose, health-care sensor, or biometric sensor). A mobile wearable device disclosed in this specification may use information sensed by at least two of these sensors in combination.

The illumination sensor **131** senses the level of illumination of surrounding light in a certain space. The illumination sensor **131** includes an element whose resistance changes depending on the intensity of the surrounding light. The illumination sensor **131** calculates variations of voltage or current caused by variations in the resistance of the element.

The wearable device memory **140** stores data that supports various functions of the wearable device **100**. The wearable device memory **140** may store multiple application programs (or applications) that run on the wearable device **100** and data and commands for operating the wearable device **100**. Moreover, the wearable device memory **140** may store image data acquired by the camera **160**.

The wearable device output unit **150** is for producing output related to visual, auditory, and tactile senses. The wearable device output unit **150** may include at least one of a display unit **151**, a sound output module **152**, a haptic module (not shown), and a light output unit (not shown).

The display unit **151** may be implemented in the form of a head mounted display (HMD). A head-mounted display is a display device, worn on the head, that has a small display optic in front of the user's eyes. The display unit **151** may be located corresponding to at least one of the left and right eyes so that an image is provided in front of the user's eyes when the use is wearing the glasses-type wearable device **100**.

The display unit **151** may project an image to the eyes through a prism. The prism may be translucent to enable the user to see the projected image together with the general view in front of the user (range of vision with the user's eyes).

As such, an image output through the display unit **151** can be seen overlapping the general view. Using this feature of the display unit, the wearable device **100** can provide augmented reality (AR) which shows a virtual image overlaid on an image of the real world or background.

The sound output module **153** outputs audio data which has been received from the wireless communication unit **110** in a call signal reception mode, a calling mode, a recording mode, a voice recognition mode, a broadcast reception mode, etc., or outputs audio data which has been stored in the memory **160**. In addition, the sound output module **153** outputs an audio signal related to a function (e.g., a call signal reception sound, a message reception sound, etc.) performed by the mobile terminal **100**. The sound output module **153** may include a speaker, a buzzer, and the like. The sound output module **153** may inform the user that it has gone into the first or second mode.

The camera **160** may include a first camera **160***a* and a second camera **160***b*.

The first camera **160***a* is located in proximity to at least one of the left and right eyes, and adapted to capture an image in front of it. Since the first camera **160***a* is positioned in proximity to an eye, the first camera **160***a* can acquire an image of the scene the user is looking at.

The second camera **160***b* is located in proximity to at least one of the left and right eyes, and adapted to capture an image of the user. According to an exemplary embodiment, the second camera **160***b* may acquire an image of the user's eye.

The camera **160** may acquire a plurality of images of the user's eye for a predetermined period of time. The period of time and the number of acquired images are set values. For example, in the first mode, the camera **160** may acquire fifty images of the user's eye for ten seconds. A plurality of images of the user's eye may be transmitted to an image processor **181**, **281**, or **381** and processed.

The camera **160** may include image sensor. The image sensor may be a CCD or CMOS. The camera **160** may further include an image processor. That is, the acquired images may be processed by the image processor and output.

The wearable device **100** may further include an infrared light source (not shown) to acquire an image of the user's eye. In this case, the camera **160** has an infrared transmitting filter mounted on it. The infrared light source emits infrared light to the user's eye. The camera **160** may output images of the user's eye representing only the frequency components of the emitted infrared light. By further including an infrared light source (not shown), the camera **160** may acquire high-resolution images of the user's eye representing only the frequency components of infrared rays.

The wearable device controller **180** controls the overall operation of the wearable device **100**. The wearable device controller **180** processes signals, data, information, etc. input or output through each of the components. The wearable device controller **180** may provide proper information or functions to the user or process them by running an application program stored in the wearable device memory **140**.

Moreover, the wearable device controller **180** may control at least some of the components. Further, the wearable device controller **180** may operate at least two of the components contained in the wearable device **100** in combination, in order to run the application program.

The wearable device controller **180** may be implemented using at least one of application specific integrated circuits (ASICs), digital signal processors (DSPs), digital signal processing devices (DSPDs), programmable logic devices (PLDs), field programmable gate arrays (FPGSs), processors, controllers, micro-controllers, microprocessors and electrical units for executing other functions.

The wearable device controller **180** may include an image processor **181**. The image processor **181** will be described in detail with reference to FIG. **4**.

The wearable device controller **180** may generate control signals based on data received from the image processor **181**.

The lighting device **200** may include a communication unit **210**, an input unit **220**, a memory **240**, an indication unit **250**, a drive unit **260**, a light emitting unit **270**, a controller **280**, and a power supply **290**.

The communication unit **210** sends and receives data by communicating with the wearable device **100**. The communication unit **210** connects with the controller **280**, and sends and receives data to and from the wearable device **100** in response to a control signal. The communication unit **210** transmits the data received from the wearable device **100** to the controller **280**.

The wireless communication unit **210** is able to communicate with the wearable device **100** over Bluetooth.

The wireless communication unit **210** may use communication protocols such as Wi-Fi Direct, RFID (Radio Frequency Identification), IrDA (Infrared Data Association), UWB (Ultra Wideband), ZigBee, and NFC (Near Field Communication), as well as Bluetooth.

The communication unit **210** may include an RF (Radio Frequency) circuit. The communication unit **210** may send and receive RF signals, i.e., electromagnetic signals. The RF circuit may convert an electrical signal into an electromagnetic signal or vice versa, and communicate with the wearable device **100** using the electromagnetic signal.

For example, the RF circuit may include an antenna system, an RF transceiver, one or more amplifiers, a tuner, one or more oscillators, a digital signal processor, a CODEC chipset, memory, etc. The RF circuit may include well-known circuitry for performing communication functions.

The communication unit **210** may receive information sensed by the sensing unit **130** by communicating with the wearable device **100** having the sensing unit **130**. For example, the communication unit **210** may receive from the wearable device **100** information on the level of illumination in the surrounding environment sensed by the illumination sensor **131**.

The communication unit **210** may receive from the wearable device **100** image data acquired by the camera **160**. For example, the communication unit **210** may receive an image of the user's eye acquired by the camera **160**.

The input unit **220** may receive the brightness of the light emitting unit **270** which is selected by the user. The input unit **220** may be embedded in the lighting device **200**. Alternatively, the input unit **220** may be configured separately from the lighting device **200**. Also, the input unit **220** may be connected to a remote controller (not shown) either by wires or wirelessly and receive user input. The input unit **220** may include a keypad, a dome switch, a touchpad (static pressure/capacitance), a jog wheel, a jog switch, and the like.

For example, if the input unit **220** is a jog wheel, the user may adjust the brightness of the lighting device **200** by turning the jog wheel. According to the user's selection, the input unit **220** may generate a brightness selection signal and output it to the controller **280**. In this case, the user may choose to switch on or off the lighting device **200** which is not powered up, and accordingly decide to apply power to the lighting device **200**.

For example, when the user chooses to increase the level of illumination of the lighting device **200**, the input unit **220** generates an illumination-up signal. On the other hand, when the user chooses to decrease the level of illumination of the lighting device **200**, the input unit **220** generates an illumination-down signal. That is, the input unit **220** may directly receive user input.

The memory **240** may store data and commands for operating the lighting device **200**.

The memory **240** may store data received from the wearable device **100**. For example, the memory **240** may store images of the user's eye received from the wearable device **100**. Alternatively, the memory **240** may store pupil images received from the wearable device **100**. Alternatively, the memory **240** may store control signals received from the wearable device **100**.

The memory **240** may store preset PIN (Personal Identification Number) information of the wearable device **100** which is used for communications security.

The memory **240** may include non-volatile memory, such as one or more magnetic disk storage devices, flash memory devices, or other non-volatile solid state memory devices. The present invention is not limited to these examples, and the memory **240** may include a readable storage medium.

For example, the memory **240** may include EEP-ROM (Electronically Erasable and Programmable Read Only Memory). Information can be written to or erased from EEP-ROM by the controller **280** during the operation of the controller **280**. EEP-ROM may be a memory device that keeps the information stored in it without erasing it even when power is lost.

The indication unit **250** externally indicates whether a communication connection is made between the lighting device **200** and the wearable device **100** or not. The indication unit **250** externally indicates whether a communication connection is currently made between the lighting device **200** and the wearable device **100** or not, in order to prevent an attempt for connection to other additional wearable devices **100** from making the control of the lighting device **200** complicated and disturbing the user settings for lighting.

The indication unit **250** may externally indicate whether the lighting device **200** goes into the first mode or the second mode.

The indication unit **250** may externally indicate through a speaker or bulb that the lighting device **200** establishes a communication connection with the wearable device **100** or goes into the first mode while connected to the wearable device **100** for communication.

The drive unit **260** receives a control signal from the controller **280**. The drive unit **260** applies driving current to the light emitting unit **270** in response to the control signal. The illumination, dimming, color temperature, color, and flickering of light emitted from the light emitting unit **270** are controlled in accordance with the driving current applied from the drive unit **260**.

The light emitting unit **270** includes a substrate and at least one light emitting element mounted on the substrate. The light emitting element emits light when powered, and its brightness may vary with the amount of power applied. Also, the color temperature of the light emitting element may vary with power, and the color of emitted light may vary from combinations of red (R), green (G), and blue (B). The light emitting unit **270** may include a plurality of LED elements. Specifically, the light emitting unit **270** includes white, red, green, and blue LED elements by reaction with fluorescent materials. The light emitting unit **270** is driven by receiving driving current from the drive unit **260**.

The controller **280** receives data from the communication unit **210**. The controller **280** controls the light emitting unit **270** based on the received data. That is, the controller **280** transmits a control signal to the drive unit **260** based on lighting control data to control the light emitting unit **270** and adjust lighting properties.

The controller **280** may include an image processor **281**. The image processor **281** will be described in detail with reference to FIG. **4**.

The controller **280** may generate control signals based on data received from the image processor **281**.

The controller **280** may generate control signals based on data stored in the memory **240**.

The controller **280** may be implemented using at least one of application specific integrated circuits (ASICs), digital signal processors (DSPs), digital signal processing devices (DSPDs), programmable logic devices (PLDs), field programmable gate arrays (FPGSs), processors, controllers, micro-controllers, microprocessors and electrical units for executing other functions.

The power supply unit **290** is connected to a power supply source and supplies electric power to the lighting device. The power supply unit **290** may include a converter that converts between AC and DC depending on the type of power used. The power supply unit **290** may further include a power conservation circuit or a voltage step-down regulator for supplying a certain level of static current.

If a plurality of wearable devices **100** are positioned in proximity to the lighting device **200**, this may cause a problem with the communication connection between the lighting device **200** and the wearable devices **100**. Also, when the lighting device **200** and the wearable device **100** are connected for communication, there may be a problem with an attempt to connect to other additional wearable devices **100**.

In this case, the controller **280** may control the communication unit **210** to form a communication channel with the first wearable device **100***a* with the highest priority according to the order of connection requests made. That is, the communication unit **210** forms a communication channel with the first wearable device **100***a* which has made the earliest connection attempt, among the plurality of wearable devices **100** that have sent and received a connection signal to and from the lighting device **200**. The communication channel is formed without entering a pin code, which simplifies the formation of a communication channel by the lighting device, requires less time, and offers convenience for use.

When a communication channel with the first wearable device **100***a* is established, the controller **280** may control the communication unit **210** not to respond to a connection signal from other wearable devices **100***b*. Accordingly, this prevents a connection between the lighting device **200** and the plurality of wearable devices **100***a* and **100***b* from making the control of the light emitting unit **270** complicated and prevents other people from changing the user settings.

In the present invention, the communication unit **210** also may form a plurality of communication channels with other wearable devices **100***b* simultaneously in response to a connection signal after forming a communication channel with the first wearable device **100***a*.

When the communication unit **210** receives a connection signal from a plurality of wearable devices, the controller **280** may receive pin codes from the plurality of wearable devices **100**, compares them with the PIN (Personal Identification Number) codes stored in the memory **240**, and control the communication unit **210** to form a communication channel with the first wearable device **100***a* which is given the highest priority, among the wearable devices **100** having a matching PIN code. In this case, the PIN codes of the communication unit **210** and the priorities of connection of the wearable devices **100** may be stored in the memory **240**.

Specifically, the controller **280** controls the communication unit **210** to transmit a PIN code request signal to the plurality of wearable devices **100** that have sent a connection signal. Afterwards, the controller **280** compares the pin codes transmitted from the plurality of the wearable devices **100** with the PIN codes stored in the memory **240** and determines the priorities of the wearable devices **100** having a matching PIN code.

Accordingly, the lighting device **200** forms a communication channel with the first wearable device **100***a* with the highest priority. The communication unit **210** does not respond to any wearable device having no matching PIN code.

This type of communication channel formation requires a PIN code when forming a communication channel, and therefore has the advantage of preventing the light emitting unit from being controlled by other wearable devices connected without permission.

FIG. **4** is a block diagram showing the components of an image processor according to the exemplary embodiment of the present invention.

(a) of FIG. **4** illustrates that the image processor **181** is included in the wearable device controller **180**. (b) of FIG. **4** illustrates that the image processor **281** is included in the controller **280** of the lighting device **200**.

The image processor **181** included in the wearable device **100** processes images based on at least one image of the user's eye acquired from the camera **160**.

The image processor **281** included in the lighting device **200** processes images based on at least one image of the user's eye received from the communication unit **210**.

The image processor **181** or **281** includes an object detector **182** or **282**, an object recognizer **183** or **283**, an object tracker **184** or **284**, and an application unit **185** or **285**.

The object detector **182** or **282** detects a pupil image from an image of the user's eye. For example, the object detector **182** or **282** can detect a pupil image using a circular detection template, a circular edge detection technique, Daugman's circular edge detection technique, etc. because the pupil is nearly round. The object detector **182** or **282** may detect a pupil image using Hough transform, Haar-like feature, AdaBoost algorithm, etc.

The object detector **182** or **282** may detect a plurality of pupil images from a plurality of images of the user's eye, respectively. The plurality of images of the user's eye is a preset number of images that are acquired for a preset period of time.

The pupil is the circle in the center of the eye, which is surrounded by the iris. The pupil is darker than the rest of the eye and normally black. Light enters the eye through the cornea and then through the pupil. Hence, the size of the pupil determines the amount of light entering the eye. That is, when the pupil contracts or expands to control the amount of light entering the eye, it changes the size of the pupil. The pupil size is controlled not by changes in shape caused by the sphincter papillae, but by the iris sphincter muscle around the pupil. When a relatively large amount of light is directed to a human eye, the pupil constricts. Constriction of the pupil reduces the amount of light entering the eye. When a relatively small amount of light is directed to the human eye, the pupil dilates and this increases the amount of light entering the eye.

The object recognizer **183** or **283** compares the size of a detected pupil image with preset first and second reference values. The first and second reference values may be stored in the wearable memory device memory **140** or the memory **240**.

The first and second reference values are reference pupil sizes that are set according to test values or accumulated pupil images. For example, if the pupil size is greater than or equal to the first reference value, it can be assumed that the amount of light directed to the human eye is small. In another example, if the pupil size is less than or equal to the second reference value, it can be assumed that the amount of light directed to the human eye is large. By comparing a pupil image of the user with the first and second reference values, it can be found out whether the right amount of light is directed to the user's eye or not.

The object recognizer **183** or **283** may calculate the average size of a plurality of pupil images received from the object detector **182** or **282**. The object recognizer **183** or **283** may compare the average size of the plurality of pupil images with the preset first and second reference values. The plurality of pupil images are detected from a preset number of images of the user's eye that are captured for a preset period of time.

The object recognizer **183** or **283** compares the position of a detected pupil image with a preset third reference value. The third reference value may be stored in the wearable device memory **140** or the memory **240**.

The third reference value is the reference position of the pupil which is set based on test values or pupil images. For example, the third reference value may be the position of the pupil when the user looks straight ahead.

The object recognizer **183** or **283** may calculate the average position of a plurality of pupil images upon receiving them from the object detector **182** or **282**. The object recognizer **183** or **283** may compare the average position of the plurality of pupil images with the third reference value. The plurality of pupil images is detected from a preset number of images of the user's eye that are captured for a preset period of time.

The object tracker **184** or **284** calculates a change in the position of a pupil image based on the result of comparison of the position of the pupil image and the third reference value. For example, the object tracker **184** or **284** calculates whether a pupil image is located above or below the third reference value.

The application unit **185** or **285** calculates the level of illumination corresponding to the result of comparison by the object recognizer **183** or **283**. For example, if the size of a pupil image is greater than or equal to the first reference value, the application unit **185** or **285** increases the level of illumination from the lighting device **200**. On the other hand, if the size of the pupil image is less than or equal to the second reference value, the application unit **185** or **285** decreases the level of illumination from the lighting device **200**.

If the lighting system includes a plurality of lighting devices **200**, the application unit **185** or **285** calculates the number of lighting devices to be activated, corresponding to the result of comparison by the object recognizer **183** or **283**. For example, if the size of a pupil image is greater than or equal to the first reference value, the application unit **185** or **285** increases the number of lighting devices to be activated. On the other hand, if the size of the pupil image is less than or equal to the second reference value, the application unit **185** or **285** decreases the number of lighting devices to be activated.

The application unit **185** or **285** calculates the level of illumination corresponding to the position change calculated by the object tracker **184** or **284**. For example, if a pupil image is located above the third reference value, the application unit **185** or **285** increases the level of illumination from the lighting device **200**. On the other hand, if the pupil image is located below the third reference value, the application unit **185** or **285** decreases the level of illumination from the lighting device **200**.

If the lighting system includes a plurality of lighting devices **200**, the application unit **185** or **285** calculates the number of lighting devices to be activated corresponding to the position change calculated by the object tracker **184** or **284**. For example, if a pupil image is located above the third reference value, the application unit **185** or **285** increases the number of lighting devices to be activated. On the other hand, if the pupil image is located below the third reference value, the application unit **185** or **285** decreases the number of lighting devices to be activated.

As described above, the lighting system according to the exemplary embodiment of the present invention can calculate the level of illumination from a lighting device or the number of lighting devices to be activated among a plurality of lighting devices, based on a pupil image of the user. Accordingly, the lighting system according to the exemplary embodiment of the present invention can provide the right level of illumination suitable for the user by controlling lighting according to pupil size. Moreover, the lighting system according to the exemplary embodiment of the present invention offers convenient lighting control for the user.

The image processor **181** and **281** may further include an image preprocessor (not shown). The image preprocessor (not shown) may perform preprocessing for changing an acquired image of the eyes of the user into an image suitable for pupil detection. The image preprocessor (not shown) can perform noise reduction, rectification, calibration, color enhancement, color space conversion (CSC), interpolation, camera gain control, etc.

FIG. **5** is a block diagram showing the components of the lighting system according to the exemplary embodiment of the present invention.

Referring to FIG. **5**, the lighting system according to the exemplary embodiment of the present invention includes a wearable device **100**, an integrated control module **300**, and a plurality of lighting devices **200** (**200*a*** to **200*n***).

Descriptions of the wearable device **100** and the lighting devices **200** (**200*a*** to **200*n***) will be omitted if they are redundant to those made with reference to FIGS. **2** to **4**.

The wearable device **100** has at least one camera **160**. The wearable device **100** communicates with the integrated control module **300**. The wearable device **100** transmits at least one image captured by the camera **160** to the integrated control module **300**. Alternatively, the wearable device **100** may transmit a control signal for controlling the lighting devices **200** (**200*a*** to **200*n***) to the integrated control module **300** according to an exemplary embodiment.

The integrated control module **300** communicates with the wearable device **10**. The integrated control module **300** receives an image of the user's eye from the wearable device **100**. The integrated control module **300** detects a pupil image based on the image of the user's eye. The integrated control module **300** controls the number of lighting devices to be activated among the plurality of lighting devices **200** (**200*a*** to **200*n***), based on the detected pupil image.

Hereinafter, the operations of the components included in the integrated control module **300** will be described.

The integrated control module **300** includes an integrated control module communication unit **310**, an integrated control module memory **340**, an integrated control module processor **380**, and an image processor **381**.

The integrated control module communication unit **310** communicates with the wearable device **100** or the plurality of lighting devices **200** (**200*a*** to **200*n***).

The integrated control module **310** sends and receives data or signals to or from the wearable device **100** and the plurality of lighting devices **200** (**200*a*** to **200*n***).

The integrated control module communication unit **310** is able to communicate with the wearable device **100** over Bluetooth.

The integrated control module communication unit **310** may use communication protocols such as Wi-Fi Direct, RFID (Radio Frequency Identification), IrDA (Infrared Data

Association), UWB (Ultra Wideband), ZigBee, and NFC (Near Field Communication), as well as Bluetooth.

The integrated control module communication unit **310** may include an RF (Radio Frequency) circuit. The integrated control module communication unit **310** may send and receive RF signals, i.e., electromagnetic signals. The RF circuit may convert an electrical signal into an electromagnetic signal or vice versa, and communicate with the wearable device **100** using the electromagnetic signal.

For example, the RF circuit may include an antenna system, an RF transceiver, one or more amplifiers, a tuner, one or more oscillators, a digital signal processor, a CODEC chipset, memory, etc. The RF circuit may include well-known circuitry for performing communication functions.

The integrated control module communication unit **310** may receive information sensed by the sensing unit **130** by communicating with the wearable device **100** having the sensing unit **130**. For example, the integrated control module communication unit **310** may receive from the wearable device **100** information on the level of illumination in the surrounding environment sensed by the illumination sensor **131**.

The integrated control module communication unit **310** may receive from the wearable device **100** image data acquired by the camera **160**. For example, the integrated control module communication unit **310** may receive an image of the user's eye acquired by the camera **160**.

The image processor **381** processes images based on the image of the user's eye received from the integrated control communication unit **310**.

The integrated control module memory **340** may store data and commands for operating the plurality of lighting devices **200** (**200***a* to **200***n*).

The integrated control module memory **340** may store data received from the wearable device **100**. For example, the integrated control module memory **340** may store images of the user's eye received from the wearable device **100**. Alternatively, the integrated control module memory **340** may store pupil images received from the wearable device **100**. Alternatively, the integrated control module memory **340** may store control signals received from the wearable device **100**.

The integrated control module memory **340** may store preset PIN (Personal Identification Number) information of the wearable device **100** which is used for communications security.

The integrated control module memory **340** may include non-volatile memory, such as one or more magnetic disk storage devices, flash memory devices, or other non-volatile solid state memory devices. The present invention is not limited to these examples, and the integrated control module memory **340** may include a readable storage medium.

For example, the integrated control module memory **340** may include EEP-ROM (Electronically Erasable and Programmable Read Only Memory). Information can be written to or erased from EEP-ROM by the integrated control module processor **380** during the operation of the integrated control module processor **380**. EEP-ROM may be a memory device that keeps the information stored in it without erasing it even when power is lost.

The integrated control module processor **380** receives data from the integrated control module communication unit **310**. The integrated control module processor **380** controls the plurality of lighting devices **200** (**200***a* to **200***n*) based on the received data. That is, the integrated control module processor **380** adjusts the number of lights when activated by transmitting a control signal to the plurality of lighting devices **200** (**200***a* to **200***n*).

The integrated control module processor **380** may generate control signals based on data received from the image processor **381**.

The integrated control module processor **380** may generate control signals based on data stored in the integrated control module memory **340**.

If a plurality of wearable devices **100** are positioned in proximity to the integrated control module **300**, this may cause a problem with the communication connection between the integrated control module **300** and the plurality of wearable devices **100**.

In this case, the integrated control module **380** only communicates with any wearable devices **100** that are authenticated based on the PIN information of the wearable devices **100** stored in the integrated control module memory **340**. If there are a plurality of authenticated wearable devices **100**, the integrated control module **300** forms a communication channel with the first wearable device **100***a* with the highest priority.

The image processor **381** detects a pupil image based on a received image of the user's eye. The image processor **381** may compare the pupil image with preset first and second reference values and calculate the number of lighting devices to be activated corresponding to the size of the detected pupil image.

The image processor **381** may compare the detected pupil image with a third reference value and calculate the number of lighting devices to be activated corresponding to the position of the detected pupil image.

The image processor **381** includes an object detector **382**, an object recognizer **383**, an object tracker **384**, and an application unit **385**.

The object detector **382** detects a pupil image from an image of the user's eye. For example, the object detector **382** can detect a pupil image using a circular detection template, a circular edge detection technique, Daugman's circular edge detection technique, etc. because the pupil is nearly round. The object detector **182** or **282** may detect a pupil image using Hough transform, Haar-like feature, AdaBoost algorithm, etc.

The object detector **382** may detect a plurality of pupil images from a plurality of images of the user's eye, respectively. The plurality of images of the user's eye is a preset number of images that are acquired for a preset period of time.

The object recognizer **383** compares the size of a detected pupil image with preset first and second reference values. The first and second reference values may be stored in the integrated control module memory **340**.

The first and second reference values are reference pupil sizes that are set according to test values or accumulated pupil images. For example, if the pupil size is greater than or equal to the first reference value, it can be assumed that the amount of light directed to the human eye is small. In another example, if the pupil size is less than or equal to the second reference value, it can be assumed that the amount of light directed to the human eye is large.

The object recognizer **383** may calculate the average size of a plurality of pupil images received from the object detector **382**. The object recognizer **383** may compare the average size of the plurality of pupil images with the preset first and second reference values. The plurality of pupil images are detected from a preset number of images of the user's eye that are captured for a preset period of time.

The object recognizer **383** compares the position of a detected pupil image with a preset third reference value. The third reference value may be stored in the integrated control module memory **340**. The third reference value is the reference position of the pupil which is set based on test values or pupil images. For example, the third reference value may be the position of the pupil when the user looks straight ahead.

The object recognizer **383** may calculate the average position of a plurality of pupil images upon receiving them from the object detector **382**. The object recognizer **383** may compare the average position of the plurality of pupil images with the third reference value. The plurality of pupil images are images is detected from the images of the user's eye that are captured a preset number of times for a preset period of time.

The object tracker **384** calculates a change in the position of a pupil image based on the result of comparison of the position of the pupil image and the third reference value. For example, the object tracker **384** calculates whether a pupil image is located above or below the third reference value.

The application unit **385** calculates the number of lighting devices to be activated c to the result of comparison by the object recognizer **383**. For example, if the size of a pupil image is greater than or equal to the first reference value, the application unit **385** increases the number of lighting devices to be activated. On the other hand, if the size of the pupil image is less than or equal to the second reference value, the application unit **385** decreases the number of lighting devices to be activated.

The application unit **385** calculates the number of lighting devices to be activated corresponding to the position change calculated by the object tracker **384**. For example, if a pupil image is located above the third reference value, the application unit **385** increases the number of lighting devices to be activated. On the other hand, if the pupil image is located below the third reference value, the application unit **385** decreases the number of lighting devices to be activated.

The image processor **381** may further include an image preprocessor (not shown). The image preprocessor (not shown) may perform preprocessing for changing an acquired image of the eyes of the user into an image suitable for pupil detection. The image preprocessor (not shown) can perform noise reduction, rectification, calibration, color enhancement, color space conversion (CSC), interpolation, camera gain control, etc.

Each of the plurality of lighting devices **200** (**200***a* to **200***n*) includes one or more light emitting elements. The plurality of lighting devices **200** (**200***a* to **200***n*) receive control signals from the integrated control module. The activation of the plurality of lighting devices **200** (**200***a* to **200***n*) and the illumination, dimming, color temperature, color, and flickering of light are controlled in response to the control signals.

FIGS. **6***a* and **6***b* are signal-flow charts of a lighting system according to a first or second exemplary embodiment of the present invention.

FIG. **6***a* illustrates that the lighting device **200** includes the image processor **281**. FIG. **6***b* illustrates that the wearable device **100** includes the image processor **181**.

Referring to FIG. **6***a*, the wearable device **100** forms a communication channel with the lighting device **200**. That is, the wearable device **100** establishes a communication connection with the lighting device **200** (S**610** and S**615**).

While connected to the lighting device **200** for communication, the wearable device **100** goes into the first mode (S**617**). Alternatively, the lighting device **200** goes into the first mode. The first mode may be a mode for controlling lighting based on an image of the user's eye (e.g., pupil image) while the wearable device **100** and the lighting device **200** are connected for communication. In this case, the wearable device controller **180** may receive user input through the wearable device input unit **120** to go into the first mode. Alternatively, the controller **280** may receive user input through the input unit **220** to go into the first mode.

While in the first mode, the wearable device **100** acquires at least one image of the user's eye through the camera **160** (S**620**). The camera **160** may acquire a plurality of images of the user's eye for a predetermined period of time. The period of time and the number of acquired images are set values.

Once at least one image of the user's eye is acquired, the wearable device **100** transmits the at least one image of the user's eye to the lighting device **200** through the wireless communication unit **110** (S**625**). The lighting device **200** receives at least one image of the user's eye from the wearable device **100** through the communication unit **210**.

Once at least one image of the user's eye is received, the lighting device **200** detects a pupil image from the at least one image of the user's eye (S**630**).

Once a pupil image is detected, the lighting device **200** tracks the pupil image (S**635**).

Afterwards, the lighting device **200** controls the level of illumination from the lighting device **200** based on the pupil image (S**640**).

Referring to FIG. **6***b*, the wearable device **100** forms a communication channel with the lighting device **200**. That is, the wearable device **100** establishes a communication connection with the lighting device **200** (S**660** and S**665**).

While connected to the lighting device **200** for communication, the wearable device **100** goes into the first mode (S**667**). Alternatively, the lighting device **200** goes into the first mode.

While in the first mode, the wearable device **100** acquires at least one image of the user's eye by the camera **160** (S**670**). The camera **160** may acquire a plurality of images for a predetermined period of time.

Once at least one image of the user's eye is acquired, the wearable device **100** detects a pupil image from the at least one image of the user's eye (S**675**).

Once a pupil is detected, the wearable device **100** tracks the pupil image (S**680**).

Afterwards, the wearable device **100** calculates the level of illumination from the lighting device **200** (S**685**).

Once the level of illumination is calculated, the wearable device **100** transmits a signal for controlling the level of illumination from the lighting device **200** (S**695**).

FIGS. **7***a* and **7***b* are flowcharts illustrating the operation of the lighting system according to the first exemplary embodiment of the present invention.

FIG. **7***a* is a flowchart referenced for describing the operation of the lighting device **200** according to the first exemplary embodiment of the present invention.

Referring to FIG. **7***a*, the controller **280** establishes a communication connection with the wearable device **100** via the communication unit **210** (S**715**).

While connected to the wearable device **100** for communication, the controller **280** goes into the first mode (S**717**). The first mode may be a mode for controlling lighting based on an image of the user's eye (e.g., pupil image) while the wearable device **100** and the lighting device **200** are connected for communication. The controller **280** may receive user input through the input unit **220** to go into the first mode.

While in the first mode, the controller **280** receives at least one image of the user's eye from the wearable device **100** (S**725**). The at least one mage of the user's eye may be an image that is acquired by the camera **160** included in the wearable device **100**. The camera **160** may acquire a plurality of images of the scene in front of the user for a predetermined period of time. The period of time and the number of acquired images are set values.

Once an image of the user's eye is received, the controller **280** detects a pupil image from the image of the user's eye (S**730**). Specifically, the operation of detecting a pupil image may be performed by the object detector **282** included in the image processor **281**, as explained with reference to FIG. **4**.

After a pupil image is detected, the controller **280** determines whether a preset number of images of the user's eye are received or not (S**732**). The preset number may be a value required to calculate the average pupil size. The preset number may be a set value.

If the preset number of images of the user's eye are received, the controller **280** calculates the average pupil size from at least one pupil image (S**734**). Specifically, the operation of calculating the average pupil size may be performed by the object recognizer **283** included in the image processor **281**, as explained with reference to FIG. **4**.

If the preset number of images of the user's eye are not received, the controller **280** receives images of the user's eye (S**725**).

Once the average pupil size is calculated, the controller **280** determines whether or not the pupil size of the user is greater than or equal to a first reference value (S**740**). The first reference value may be stored in the memory **240**. The first reference value is a reference pupil size that is set according to test values or accumulated pupil images. For example, if the pupil size is greater than or equal to the first reference value, it can be assumed that the amount of light directed to the human eye is small. Specifically, the determination of pupil size may be performed by the object recognizer **283** included in the image processor **281**, as explained with reference to FIG. **4**.

If the pupil size of the user is greater than or equal to the first reference value, the controller **280** transmits a control signal to the drive unit **260** to increase the level of illumination from the light emitting unit **270** (S**741**).

In step S**740**, if the pupil size of the user is not greater than or equal to the first reference value, the controller **280** determines whether the average pupil size of the user is less than or equal to a second reference value (S**742**). The second reference value may be stored in the memory **240**. The second reference value is a reference pupil size that is set according to test values or accumulated pupil images. For example, if the pupil size is less than or equal to the second reference value, it can be assumed that the amount of light directed to the human eye is large. Specifically, the determination of pupil size may be performed by the object recognizer **283** included in the image processor **281**, as explained with reference to FIG. **4**.

If the pupil size of the user is less than or equal to the second reference value, the controller **280** transmits a control signal to the drive unit **260** to decrease the level of illumination from the light emitting unit **270** (S**743**).

The operation of calculating the level of illumination corresponding to pupil size may be performed by the application unit **285** included in the image processor **281**, as explained with reference to FIG. **4**. The controller **280** generates a control signal based on the result of calculation by the application unit **285**.

FIG. **7***b* is a flowchart referenced for describing the operation of the wearable device **100** according to the first exemplary embodiment of the present invention.

Referring to FIG. **7***b*, the wearable device controller **180** establishes a communication connection with the lighting device **200** via the wireless communication unit **110** (S**760**).

While connected to the lighting device **200** for communication, the wearable device controller **180** goes into the first mode (S**762**). The first mode may be a mode for controlling lighting based on an image of the user's eye (e.g., pupil image) while the wearable device **100** and the lighting device **200** are connected for communication. The wearable device controller **180** may receive user input through the wearable device input unit **120** to go into the first mode.

While in the first mode, the wearable device controller **180** acquires at least one image of the user's eye from the wearable device **100** (S**770**). The at least one image of the user's eye may be an image that is acquired by the camera **160** included in the wearable device **100**. The camera **160** may acquire a plurality of images for a predetermined period of time. The period of time and the number of acquired images are set values.

Once an image of the user's eye is acquired, the wearable device controller **180** detects a pupil image from the image of the user's eye (S**775**). Specifically, the operation of detecting a pupil image may be performed by the object detector **182** included in the image processor **181**, as explained with reference to FIG. **4**.

After a pupil image is detected, the wearable device controller **180** determines whether a preset number of images of the user are acquired or not (S**777**). The preset number may be a value required to calculate the average pupil size. The preset number may be a set value.

If the preset number of images of the user's eye are acquired, the wearable device controller **180** calculates the average pupil size from at least one pupil image (S**779**). Specifically, the operation of calculating the average pupil size may be performed by the object recognizer **183** included in the image processor **181**, as explained with reference to FIG. **4**.

If the preset number of images of the user's eye are not acquired, the wearable device controller **180** receives images of the user's eye (S**770**).

Once the average pupil size is calculated, the wearable device controller **180** determines whether or not the pupil size of the user is greater than or equal to a first reference value (S**785**). The first reference value may be stored in the wearable device memory **140**. The first reference value is a reference pupil size that is set according to test values or accumulated pupil images. For example, if the pupil size is greater than or equal to the first reference value, it can be assumed that the amount of light directed to the human eye is small. Specifically, the determination of pupil size may be performed by the object recognizer **183** included in the image processor **181**, as explained with reference to FIG. **4**.

If the pupil size of the user is greater than or equal to the first reference value, the wearable device controller **180** transmits a signal to the lighting device **200** to increase the level of illumination (S**786**).

In step S**785**, if the pupil size of the user is not greater than or equal to the first reference value, the wearable device controller **180** determines whether the average pupil size of the user is less than or equal to a second reference value (S**787**). The second reference value may be stored in the wearable device memory **140**. The second reference value is a reference pupil size that is set according to test values or accumulated pupil images. For example, if the pupil size is less than or equal to the second reference value, it can be assumed that the amount of light directed to the human eye is large. Specifically, the determination of pupil size may be performed by the object recognizer **183** included in the image processor **181**, as explained with reference to FIG. **4**.

If the pupil size of the user is less than or equal to the second reference value, the wearable device controller **180** transmits a signal to the lighting device **200** to increase the level of illumination (S**788**).

The operation of calculating the level of illumination corresponding to pupil size may be performed by the application unit **185** included in the image processor **181**, as explained with reference to FIG. **4**. The wearable device controller **180** generates a control signal based on the result of calculation by the application unit **185** and transmits it to the lighting device **200**.

FIG. **8** is a view referenced to describe the operation of receiving an image in the first mode according to an exemplary embodiment of the present invention.

FIG. **8** illustrates the operation of the lighting system in the first mode. The operation of the lighting system in the second mode may be identical to the operation of the lighting system in the first mode.

Referring to FIG. **8**, a communication connection is established between the wearable device **100** and the lighting device **200** at t**1**.

The wearable device **100** and the lighting device **200** go into the first mode at t**2**. The first mode may be a mode for controlling lighting based on an image of the user's eye (e.g., pupil image) while the wearable device **100** and the lighting device **200** are connected for communication. They may go into the first mode upon receiving user input through the wearable device input **120** or the input unit **220**.

The wearable device **100** acquires images of the user's eye at t**3**, t**4**, and t**5**. The lighting device **200** receives images of the user's eye from the wearable device **100**. The images acquired or received at t**3**, t**4**, and t**5** are deemed as valid images. That is, if the wearable device **100** and the lighting device **200** are in the first mode, the acquired or received images are deemed as valid images.

The first mode is disabled at t**6**. The first mode may be disabled upon receiving user input through the wearable device input unit **120** or the input unit **220**.

The wearable device **100** may acquire images of the user's eye at t**7** and t**8**. The lighting device **200** may receive images of the user's eye from the wearable device **100**. The images acquired or received at t**7** and t**8** are deemed as invalid images. That is, if the wearable device **100** and the lighting device **200** are not in the first mode, the acquired or received images are deemed as invalid images.

The communication connection between the wearable device **100** and the lighting device **200** is released at t**9**.

FIG. **9** is an illustration of the operation of the lighting system according to the first exemplary embodiment of the present invention.

Referring to FIG. **9**, the controller **280** establishes a communication connection with the wearable device **100** via the communication unit **210**. While connected to the wearable device **100** for communication, the controller **280** goes into the first mode. While in the first mode, the controller **280** receives at least one image of the user's eye from the wearable device **100**. Once an image of the user's eye is received, the controller **280** detects a pupil image from the image of the user's eye. If a preset number of images of the user's eye are received, the controller **280** calculates the average pupil size from at least one pupil image.

The controller **280** determines whether the pupil size of the user is greater than or equal to a first reference value **910**.

If the pupil size of the user is greater than or equal to the first reference value as shown in (a) of FIG. **9**, the controller **280** transmits a control signal to the drive unit **260** to increase the level of illumination from the light emitting unit **270** as shown in (c) of FIG. **9**.

If the pupil size of the user is not greater than or equal to the first reference value, the controller **280** determines whether the average pupil size of the user is less than or equal to a second reference value **920**.

If the pupil size of the user is less than or equal to the second reference value as shown in (b) of FIG. **9**, the controller **280** transmits a control signal to the drive unit **260** to decrease the level of illumination from the light emitting unit **270** as shown in (c) of FIG. **9**.

FIGS. **10***a* and **10***b* are flowcharts illustrating the operation of the lighting system according to the second exemplary embodiment of the present invention.

FIG. **10***a* is a flowchart referenced for describing the operation of the lighting device **200** according to the second exemplary embodiment of the present invention.

Referring to FIG. **10***a*, the controller **280** establishes a communication connection with the wearable device **100** via the communication unit **210** (S**1015**).

While connected to the wearable device **100** for communication, the controller **280** goes into the first mode (S**1017**). The first mode may be a mode for controlling lighting based on an image of the user's eye (e.g., pupil image) while the wearable device **100** and the lighting device **200** are connected for communication. The controller **280** may receive user input through the input unit **220** to go into the first mode.

While in the first mode, the controller **280** receives at least one image of the user's eye from the wearable device **100** (S**1025**). The at least one image of the user's eye may be an image that is acquired by the camera **160** included in the wearable device **100**. The camera **160** may acquire a plurality of images of the user's eye for a predetermined period of time. The period of time and the number of acquired images are set values.

Once an image of the user's eye is received, the controller **280** detects a pupil image from the image of the user's eye (S**1030**). Specifically, the operation of detecting a pupil image may be performed by the object detector **282** included in the image processor **281**, as explained with reference to FIG. **4**.

After a pupil image is detected, the controller **280** determines whether a preset number of images of the user's eye are received or not (S**1032**). The preset number may be a value required to calculate the average pupil position. The preset number may be a set value.

If the preset number of images of the user's eye are received, the controller **280** tracks the position of at least one pupil image (S**1034**).

The controller **280** compares the position of a detected pupil image with a preset third reference value. The third reference value may be stored in the memory **240**. The third reference value is the reference position of the pupil which is set based on test values or pupil images. For example, the third reference value may be the position of the pupil when the user looks straight ahead. Specifically, the operation of comparing the position of a pupil image with the third reference value may be performed by the object detector **282** included in the image processor **281**, as explained with reference to FIG. **4**.

The controller **280** calculates a change in the position of a pupil image based on the result of comparison of the position of the pupil image and the third reference value. For example, the controller **280** calculates whether a pupil image is located above or below the third reference value. Specifically, the operation of calculating a change in the position of a pupil image may be performed by the object tracker **283** included in the image processor **281**, as explained with reference to FIG. **4**.

If the preset number of images of the user's eye are not received, the controller **280** receives images of the user's eye (S**1025**).

Once a change in the position of the pupil image is calculated, the controller **280** determines whether the user's pupil is located above the third reference value or not (S**1040**).

If the image of the user's pupil is located above the third reference value, the controller **280** transmits a control signal to the drive unit **260** to increase the level of illumination from the light emitting unit **270** (S**1041**).

In step S**1040**, if the image of the user's pupil is not located above the third reference value, the controller **280** determines whether the image of the user's pupil is located below the third reference value or not (S**1042**).

If the image of the user's pupil is located below the third reference value, the controller **280** transmits a control signal to the drive unit **260** to decrease the level of illumination from the light emitting unit **270** (S**1043**).

The operation of calculating the level of illumination corresponding to the position of a pupil image may be performed by the application unit **285** included in the image processor **281**, as explained with reference to FIG. **4**. The controller **280** generates a control signal based on the result of comparison by the application unit **285**.

FIG. **10***b* is a flowchart referenced for describing the operation of the wearable device **100** according to the second exemplary embodiment of the present invention.

Referring to FIG. **10***b*, the wearable device controller **180** establishes a communication connection with the lighting device **200** via the communication unit **110** (S**1060**).

While connected to the lighting device **200** for communication, the wearable device controller **180** goes into the first mode (S**1062**). The first mode may be a mode for controlling lighting based on an image of the user's eye (e.g., pupil image) while the wearable device **100** and the lighting device **200** are connected for communication. The wearable device controller **180** may receive user input through the wearable device input unit **120** to go into the first mode.

While in the first mode, the wearable device controller **180** receives at least one image of the user's eye from the wearable device **100** (S**1070**). The at least one image of the user's eye may be an image that is acquired by the camera **160** included in the wearable device **100**. The camera **160** may acquire a plurality of images of the user's eye for a predetermined period of time. The period of time and the number of acquired images are set values.

Once an image of the user's eye is acquired, the wearable device controller **180** detects a pupil image from the image of the user's eye (S**1075**). Specifically, the operation of detecting a pupil image may be performed by the object detector **182** included in the image processor **181**, as explained with reference to FIG. **4**.

After a pupil image is detected, the wearable device controller **180** determines whether a preset number of images of the user's eye are received or not (S**1077**). The preset number may be a value required to calculate the average pupil position. The preset number may be a set value.

If the preset number of images of the user's eye are received, the wearable device controller **180** tracks the position of at least one pupil image (S**1079**).

The wearable device controller **180** compares the position of a detected pupil image with a preset third reference value. The third reference value may be stored in the wearable device memory **140**. The third reference value is the reference position of the pupil which is set based on test values or pupil images. For example, the third reference value may be the position of the pupil when the user looks straight ahead. Specifically, the operation of comparing the position of a pupil image with the third reference value may be performed by the object detector **182** included in the image processor **181**, as explained with reference to FIG. **4**.

The wearable device controller **180** calculates a change in the position of a pupil image based on the result of comparison of the position of the pupil image and the third reference value. For example, the wearable device controller **180** calculates whether a pupil image is located above or below the third reference value. Specifically, the operation of calculating a change in the position of a pupil image may be performed by the object tracker **183** included in the image processor **181**, as explained with reference to FIG. **4**.

If the preset number of images of the user's eye are not received, the wearable device controller **180** receives images of the user's eye (S**1070**).

Once a change in the position of the pupil image is calculated, the wearable device controller **180** determines whether the user's pupil is located above the third reference value or not (S**1085**).

If the image of the user's pupil is located above the third reference value, the wearable device controller **180** transmits a signal to the lighting device **200** to increase the level of illumination (S**1086**).

In step S**1085**, if the image of the user's pupil is not located above the third reference value, the wearable device controller **180** determines whether the image of the user's pupil is located below the third reference value or not (S**1087**).

If the image of the user's pupil is located below the third reference value, the wearable device controller **180** transmits a signal to the lighting device **200** to decrease the level of illumination (S**1088**).

The operation of calculating the level of illumination corresponding to the position of a pupil image may be performed by the application unit **185** included in the image processor **181**, as explained with reference to FIG. **4**. The wearable device controller **180** generates a control signal based on the result of comparison by the application unit **185** and transmits it to the lighting device **200**.

FIG. **11** is an illustration of the operation of the lighting system according to the second exemplary embodiment of the present invention.

Referring to FIG. **11**, the controller **280** establishes a communication connection with the wearable device **100** via the communication unit **210**. While connected to the wearable device **100** for communication, the controller **280** goes into the first mode. While in the first mode, the controller **280** receives at least one image of the user's eye from the wearable device **100**. Once an image of the user's eye is received, the controller **280** detects a pupil image from the image of the user's eye. If a preset number of images of the user's eye are received, the controller **280** tracks the position of at least one pupil image.

The controller **280** determines whether the user's pupil is located above the third reference value **1110** or not. If the pupil **1120** is located above a third reference value **1110** as shown in (a) of FIG. **11**, the controller **280** transmits a control signal to the drive unit **260** to increase the level of illumination from the light emitting unit **270** as shown in (c) of FIG. **11**.

If the image of the user's pupil is not located above the third reference value **1110**, the controller **280** determines whether the image of the user's pupil is located below the third reference value **1110** or not.

If the image of the user's pupil is located below the third reference value **1110** as shown in (b) of FIG. **11**, the controller **280** transmits a control signal to the drive unit **260** to decrease the level of illumination from the light emitting unit **270** as shown in (c) of FIG. **11**.

FIGS. **12***a* and **12***b* are signal-flow charts of a lighting system according to a third or fourth exemplary embodiment of the present invention.

FIG. **12***a* illustrates that the integrated control module **300** includes the image processor **381**. FIG. **12***b* illustrates that the wearable device **100** includes the image processor **181**.

Referring to FIG. **12***a*, the wearable device **100** forms a communication channel with the integrated control module **300**. That is, the wearable device **100** establishes a communication connection with the integrated control module **300** (S**1210** and S**1215**).

While connected to the integrated control module **300** for communication, the wearable device **100** goes into the second mode (S**1217**). Alternatively, the integrated control module **300** goes into the second mode. The second mode may be a mode for controlling the lighting device **200** based on an image of the user's eye (e.g., pupil image) while the wearable device **100** and the integrated control module **300** are connected for communication. In this case, the wearable device controller **180** may receive user input through the wearable device input unit **120** to go into the second mode.

While in the second mode, the wearable device **100** acquires at least one image of the user's eye by the camera **160** (S**1220**). The camera **160** may acquire a plurality of images for a predetermined period of time. The period of time and the number of acquired images are set values.

Once at least one image of the user's eye is acquired, the wearable device **100** transmits the at least one image of the user's eye to the integrated control module **300** through the wireless communication unit **110** (S**1225**). The integrated control module **300** receives at least one image of the user's eye from the wearable device **100** via the integrated control module communication unit **310**.

Once at least one image of the user's eye is received, the integrated control module **300** detects a pupil image from the at least one image of the user's eye (S**1230**).

Once a pupil image is detected, the integrated control module **300** tracks the pupil image (S**1235**).

Afterwards, the integrated control module **300** calculates the number of lighting devices to be activated among the plurality of lighting devices **200**, based on the pupil image (S**1240**).

Next, the integrated control module **300** transmits a control signal to the lighting device **200** based on the result of calculation (S**1245**).

Referring to FIG. **12***b*, the wearable device **100** forms a communication channel with the integrated control module **300**. That is, the wearable device **100** establishes a communication connection with the integrated control module **300** (S**1260** and S**1265**).

While connected to the integrated control module **300** for communication, the wearable device **100** goes into the second mode (S**1267**). Alternatively, the lighting device **200** goes into the second mode.

While in the second mode, the wearable device **100** acquires at least one image of the user's eye by the camera **160** (S1270). The camera **160** may acquire a plurality of images of the user's eye for a predetermined period of time.

Once at least one image of the user's eye is acquired, the wearable device **100** detects a pupil image from the at least one image of the user's eye (S**1275**).

Once a pupil image is detected, the wearable device **100** tracks the pupil image (S**1280**).

Afterwards, the wearable device **100** transmits the pupil image tracking result to the integrated control module **300** (S**1285**).

Afterwards, the integrated control module **300** calculates the number of lighting devices to be activated among the plurality of lighting devices **200**, based on the pupil image (S**1290**).

Next, the integrated control module **300** transmits a control signal to the lighting device **200** based on the result of calculation (S**1295**).

FIGS. **13***a* and **13***b* are signal-flow charts of the lighting system according to the third exemplary embodiment of the present invention.

FIG. **13***a* is a flowchart referenced for describing the operation of the integrated control module **300** according to the third exemplary embodiment of the present invention.

Referring to FIG. **13***a*, the integrated control module processor **380** establishes a communication connection with the wearable device **100** via the integrated control module communication unit **310** (S**1315**).

While connected to the wearable device **100** for communication, the integrated control module processor **380** goes into the second mode (S**1317**). The second mode may be a mode for controlling lighting based on an image of the user's eye (e.g., pupil image) while the wearable device **100** and the integrated control module **300** are connected for communication. The integrated control module processor **380** may receive user input through an integrated control module processor input unit (not shown) to go into the second mode.

While in the second mode, the integrated control module processor **380** receives at least one image of the user's eye from the wearable device **100** (S**1325**). The at least one image of the user's eye may be an image that is acquired by the camera **160** included in the wearable device **100**. The camera **160** may acquire a plurality of images of the user's eye for a predetermined period of time. The period of time and the number of acquired images are set values.

Once an image of the user's eye is received, the integrated control module processor **380** detects a pupil image from the image of the user's eye (S**1330**). Specifically, the operation of detecting a pupil image may be performed by the object detector **382** included in the image processor **381**, as explained with reference to FIG. **5**.

After a pupil image is detected, the integrated control module controller **380** determines whether a preset number of images of the user's eye are received or not (S**1332**). The preset number may be a value required to calculate the average pupil size. The preset number may be a set value.

If the preset number of images of the user's eye are received, the integrated control module controller **380** calculates the average pupil size from at least one pupil image (S**1334**). Specifically, the operation of calculating the average pupil size may be performed by the object recognizer **383** included in the image processor **381**, as explained with reference to FIG. **5**.

If the preset number of images of the user's eye are not received, the integrated control module controller **380** receives images of the user's eye (S**1325**).

Once the average pupil size is calculated, the integrated control module controller **380** determines whether or not the pupil size of the user is greater than or equal to a first reference value (S**1340**). The first reference value may be stored in the integrated control module memory **340**. The first reference value is a reference pupil size that is set according to test values or accumulated pupil images. For example, if the pupil size is greater than or equal to the first reference value, it can be assumed that the amount of light directed to the human eye is small. Specifically, the determination of pupil size may be performed by the object recognizer **383** included in the image processor **381**, as explained with reference to FIG. **5**.

If the pupil size of the user is greater than or equal to the first reference value, the integrated control module controller **380** increases the number of lighting devices to be activated among the plurality of lighting devices **200** (S**1341**).

In step S**1340**, if the pupil size of the user is not greater than or equal to the first reference value, the integrated control module controller **380** determines whether the average pupil size of the user is less than or equal to a second reference value (S**1342**). The second reference value may be stored in the integrated control module memory **340**. The second reference value is a reference pupil size that is set according to test values or accumulated pupil images. For example, if the pupil size is less than or equal to the second reference value, it can be assumed that the amount of light directed to the human eye is large. Specifically, the determination of pupil size may be performed by the object recognizer **383** included in the image processor **381**, as explained with reference to FIG. **5**.

If the pupil size of the user is less than or equal to the second reference value, the integrated control module controller **380** decreases the number of lighting devices to be activated among the plurality of lighting devices **200** (S**1343**).

The operation of calculating the level of illumination corresponding to pupil size may be performed by the application unit **385** included in the image processor **381**, as explained with reference to FIG. **5**. The integrated control module controller **380** generates a control signal based on the result of calculation by the application unit **385**.

FIG. **13***b* is a flowchart referenced for describing the operation of the wearable device **100** according to the third exemplary embodiment of the present invention.

Referring to FIG. **13***b*, the wearable device controller **180** establishes a communication connection with the integrated control module **300** via the wireless communication unit **110** (S**1360**).

While connected to the integrated control module **300** for communication, the wearable device controller **180** goes into the second mode (S**1362**). The second mode may be a mode for controlling lighting based on an image of the user's eye (e.g., pupil image) while the wearable device **100** and the integrated control module **300** are connected for communication. The wearable device controller **180** may receive user input through the wearable device input unit **120** to go into the second mode.

While in the second mode, the wearable device controller **180** receives at least one image of the user's eye from the wearable device **100** (S**1370**). The at least one image of the user's eye may be an image that is acquired by the camera **160** included in the wearable device **100**. The camera **160** may acquire a plurality of images of the user's eye for a predetermined period of time. The period of time and the number of acquired images are set values.

Once an image of the user's eye is acquired, the wearable device controller **180** detects a pupil image from the image of the user's eye (S**1375**). Specifically, the operation of detecting a pupil image may be performed by the object detector **182** included in the image processor **181**, as explained with reference to FIG. **4**.

After a pupil image is detected, the wearable device controller **180** determines whether a preset number of images of the user's eye are received or not (S**1377**). The preset number may be a value required to calculate the average pupil size. The preset number may be a set value.

If the preset number of images of the user's eye are acquired, the wearable device controller **180** calculates the average pupil size from at least one pupil image (S**1379**). Specifically, the operation of calculating the average pupil size may be performed by the object recognizer **183** included in the image processor **181**, as explained with reference to FIG. **4**.

If the preset number of images of the user's eye are not received, the wearable device controller **180** receives images of the user's eye (S**1370**).

Once the average pupil size is calculated, the wearable device controller **180** transmits average pupil size data to the integrated control module **300** (S**1385**).

The integrated control module **300** receives the average pupil size data. The operation of controlling the number of lighting devices to be activated when the integrated control module **300** has received the average pupil size data is identical to steps S**1340**, S**1341**, S**1342**, and S**1343** of FIG. **13***a*.

FIG. **14** is an illustration of the operation of the lighting system according to the third exemplary embodiment of the present invention.

Referring to FIG. **14**, the integrated control module processor **380** establishes a communication connection with the wearable device **100** via the integrated control module communication unit **310**. While connected to the wearable device **100** for communication, the integrated control module processor **380** goes into the second mode. While in the second mode, the integrated control module processor **380** receives at least one image of the user's eye from the wearable device **100**. Once an image of the user's eye is received, the integrated control module processor **380** detects a pupil image from the image of the user's eye. If a preset number of images of the user's eye are received, the integrated control module processor **380** calculates the average pupil size from at least one pupil image.

The integrated control module processor **380** determines whether or not the user's pupil size **1405** is greater than or equal to a first reference value **1410**.

If the pupil size **1405** of the user is greater than or equal to the first reference value as shown in (a) of FIG. **14**, the integrated control module processor **380** increases the number of lighting devices to be activated among the plurality of lighting devices **200** as shown in (c) of FIG. **14**. For example, it is assumed that only the second, fifth, eighth, and eleventh lighting devices **200***b*, **200***e*, **200***h*, and **200***k* out of the plurality of lighting devices **200** (**200***a* to **200***l*) are activated. In this case, if the pupil size **1405** of the user is greater than or equal to the first reference value, the integrated control module processor **380** may further activate the first, third, fourth, sixth, seventh, ninth, tenth, and twelfth lighting devices **200***a*, **200***c*, **200***d*, **200***f*, **200***g*, **200***i*, **200***j*, and **200***l*.

If the pupil size of the user is not greater than or equal to the first reference value **1410**, the integrated control module processor **380** determines whether the average pupil size **1415** of the user is less than or equal to a second reference value **1420**.

If the pupil size **1415** of the user is less than or equal to the second reference value **1420** as shown in (b) of FIG. **14**, the integrated control module processor **380** decreases the number of lighting devices to be activated among the plurality of lighting devices **200** as shown in (c) of FIG. **14**. For example, it is assumed that all of the first to twelfth lighting devices **200** (**200***a* to **200***l*) are activated. In this case, if the pupil size **1415** of the user is less than or equal to the second reference value, the integrated control module processor **380** may turn off the first, third, fourth, sixth, seventh, ninth, tenth, and twelfth lighting devices **200***a*, **200***c*, **200***d*, **200***f*, **200***g*, **200***i*, **200***j*, and **200***l* to deactivate them.

FIGS. **15***a* and **15***b* are signal-flow charts of the lighting system according to the fourth exemplary embodiment of the present invention.

FIG. **15***a* is a flowchart referenced for describing the operation of the integrated control module **300** according to the fourth exemplary embodiment of the present invention.

Referring to FIG. **15***a*, the integrated control module processor **380** establishes a communication connection with the wearable device **100** via the integrated control module communication unit **310** (S**1515**).

While connected to the wearable device **100** for communication, the integrated control module processor **380** goes into the second mode (S**1517**). The second mode may be a mode for controlling lighting based on an image of the user's eye (e.g., pupil image) while the wearable device **100** and the integrated control module **300** are connected for communication. The integrated control module processor **380** may receive user input through the input unit **220** to go into the second mode.

While in the second mode, the integrated control module processor **380** receives at least one image of the user's eye from the wearable device **100** (S**1525**). The at least one image of the user's eye may be an image that is acquired by the camera **160** included in the wearable device **100**. The camera **160** may acquire a plurality of images of the user's eye for a predetermined period of time. The period of time and the number of acquired images are set values.

Once an image of the user's eye is received, the integrated control module processor **380** detects a pupil image from the image of the user's eye (S**1530**). Specifically, the operation of detecting a pupil image may be performed by the object detector **382** included in the image processor **381**, as explained with reference to FIG. **5**.

After a pupil image is detected, the integrated control module controller **380** determines whether a preset number of images of the user's eye are received or not (S**1532**). The preset number may be a value required to calculate the average pupil position. The preset number may be a set value.

If the preset number of images of the user's eye are received, the integrated control module processor **380** tracks the position of at least one pupil image (S**1534**).

The integrated control module processor **380** compares the position of a detected pupil image with a preset third reference value. The third reference value may be stored in the integrated control module memory **340**. The third reference value is the reference position of the pupil which is set based on test values or pupil images. For example, the third reference value may be the position of the pupil when the user looks straight ahead. Specifically, the operation of comparing the position of a pupil image with the third reference value may be performed by the object detector **382** included in the image processor **381**, as explained with reference to FIG. **5**.

The integrated control module processor **380** calculates a change in the position of a pupil image based on the result of comparison of the position of the pupil image and the third reference value. For example, the integrated control module processor **380** calculates whether a pupil image is located above or below the third reference value. Specifically, the operation of calculating a change in the position of a pupil image may be performed by the object tracker **383** included in the image processor **381**, as explained with reference to FIG. **4**.

If the preset number of images of the user's eye are not received, the integrated control module processor **380** receives images of the user's eye (S**1525**).

Once a change in the position of the pupil image is calculated, the integrated control module processor **380** determines whether the user's pupil is located above the third reference value or not (S**1540**).

If the image of the user's pupil is located above the third reference value, the integrated control module processor **380** increases the number of lighting devices to be activated among the plurality of lighting devices (S**1541**).

In step S**1540**, if the image of the user's pupil is not located above the third reference value, the integrated control module processor **380** determines whether the image of the user's pupil is located below the third reference value or not (S**1542**).

If the image of the user's pupil is located below the third reference value, the integrated control module processor **380** decreases the number of lighting devices to be activated among the plurality of lighting devices (S**1543**).

The operation of calculating the level of illumination corresponding to the position of a pupil image may be performed by the application unit **385** included in the image processor **381**, as explained with reference to FIG. **5**. The integrated control module processor **380** generates a control signal based on the result of comparison by the application unit **285**.

FIG. **15***b* is a flowchart referenced for describing the operation of the wearable device **100** according to the second exemplary embodiment of the present invention.

Referring to FIG. **15***b*, the wearable device controller **180** establishes a communication connection with the integrated control module **300** via the wireless communication unit **110** (S**1560**).

While connected to the integrated control module **300** for communication, the wearable device controller **180** goes into the second mode (S**1562**). The second mode may be a mode for controlling lighting based on an image of the user's eye (e.g., pupil image) while the wearable device **100** and the integrated control module **300** are connected for communication. The wearable device controller **180** may receive user input through the wearable device input unit **120** to go into the second mode.

While in the second mode, the wearable device controller **180** receives at least one image of the user's eye from the wearable device **100** (S**1570**). The at least one image of the user's eye may be an image that is acquired by the camera **160** included in the wearable device **100**. The camera **160** may acquire a plurality of images of the user's eye for a predetermined period of time. The period of time and the number of acquired images are set values.

Once an image of the user's eye is acquired, the wearable device controller **180** detects a pupil image from the image of the user's eye (S**1575**). Specifically, the operation of detecting a pupil image may be performed by the object detector **182** included in the image processor **181**, as explained with reference to FIG. **4**.

After a pupil image is detected, the wearable device controller **180** determines whether a preset number of images of the user's eye are received or not (S**1577**). The preset number may be a value required to calculate the average pupil position. The preset number may be a set value.

If the preset number of images of the user's eye are received, the wearable device controller **180** tracks the position of at least one pupil image (S**1579**).

If the preset number of images of the user's eye are not received, the wearable device controller **180** receives images of the user's eye (S1570).

Once the position of at least one pupil image is detected, the wearable device controller **180** transmits pupil image position tracking data to the integrated control module **300** (S**1585**).

The integrated control module **300** receives the pupil image position tracking data. The operation of controlling the number of lighting devices to be activated when the integrated control module **300** has received the pupil image position tracking data is identical to steps S**1540**, S**1541**, S**1542**, and S**1543** of FIG. **15***a*.

FIG. **16** is an illustration of the operation of the lighting system according to the fourth exemplary embodiment of the present invention.

Referring to FIG. **16**, the integrated control module processor **380** establishes a communication connection with the wearable device **100** via the integrated control module communication unit **310**. While connected to the wearable device **100** for communication, the integrated control module processor **380** goes into the second mode. While in the second mode, the integrated control module processor **380** receives at least one image of the user's eye from the wearable device **100**. Once an image of the user's eye is received, the integrated control module processor **380** detects a pupil image from the image of the user's eye. If a preset number of images of the user's eye are received, the integrated control module processor **380** tracks the position of at least one pupil image.

The integrated control module processor **380** determines whether the user's pupil **1620** is located above a third reference value **1610** or not. If the pupil **1620** is located above the third reference value **1610** as shown in (a) of FIG. **16**, the integrated control module processor **380** increases the number of lighting devices to be activated among the plurality of lighting devices **200** as shown in (c) of FIG. **16**. For example, it is assumed that only the second, fifth, eighth, and eleventh lighting devices **200***b*, **200***e*, **200***h*, and **200***k* out of the plurality of lighting devices **200** (**200***a* to **200***l*) are activated. In this case, if the pupil **1620** is located above the third reference value **1610**, the integrated control module processor **380** may further activate the first, third, fourth, sixth, seventh, ninth, tenth, and twelfth lighting devices **200***a*, **200***c*, **200***d*, **200***f*, **200***g*, **200***i*, **200***j*, and **200***l*.

If the pupil is not located above the third reference value, the integrated control module processor **380** determines whether the image of the user's pupil **1620** is located below the third reference value **1610**.

If the image of the user's pupil **1620** is located below the third reference value **1610** as shown in (b) of FIG. **16**, the integrated control module processor **380** decreases the number of lighting devices to be activated among the plurality of lighting devices **200** as shown in (d) of FIG. **16**. For example, it is assumed that all of the first to twelfth lighting devices **200** (**200***a* to **200***l*) are activated. In this case, if the image of the user's pupil **1620** is located below the third reference value **1610**, the integrated control module processor **380** may turn off the first, third, fourth, sixth, seventh, ninth, tenth, and twelfth lighting devices **200***a*, **200***c*, **200***d*, **200***f*, **200***g*, **200***i*, **200***j*, and **200***l* to deactivate them.

FIG. **17** is an illustration of a lighting control screen displayed on a wearable device according to an exemplary embodiment of the present invention.

Referring to FIG. **17**, the wearable device controller **180** establishes a communication connection with the lighting device **200** or the integrated control module **300**. While connected to the lighting device **200** or the integrated control module **300** for communication, the wearable device controller **180** goes into the first mode or the second mode. In this case, the wearable device controller **180** may go into the first mode upon receiving user input through the wearable device input unit **120**. While in the first mode or the second mode, the wearable device controller **180** displays a control screen related to the control of the lighting device **200**. The current illumination, set illumination, total number of lights, and number of activated lights may be displayed on the control screen.

Meanwhile, this invention can be implemented in processor-readable codes in a processor-readable recording medium provided on the SCA-based application system. Here, the processor-readable recording medium includes all kinds of recording devices for storing processor-readable data. Examples of the processor-readable recording medium include includes a computer-readable storage medium such as ROM, RAM, a CD-ROM, magnetic tapes, floppy disks, and optical data storage devices, and a means implemented in the form of carrier waves, for example, transmission via the Internet. The processor-readable recording medium may be distributed among computer systems connected to a network, and processor-readable codes may be stored and executed in a decentralized fashion.

In order to overcome the above-described problems, an aspect of the present invention provides a lighting system and a control method thereof which allow for lighting control based on images of a user's eye.

In one aspect, an exemplary embodiment of the present invention is directed to a lighting device including: a communication unit that communicates with a wearable device with at least one camera and receives an image of a user's eye captured by the camera; a light emitting unit including one or more light emitting elements; and a controller that detects a pupil image based on the image of the user's eye and controls the light emitting unit based on the pupil image.

In another aspect, an exemplary embodiment of the present invention is directed to a lighting system including: a plurality of lighting devices each including one or more light emitting units; and an integrated control module; and an integrated control module that communicates with the wearable device with at least one camera, receives an image of a user's eye captured by the camera, detects a pupil image based on the image, and controls the number of lighting devices to be activated among the plurality of lighting devices based on the pupil image.

In still another aspect, an exemplary embodiment of the present invention is directed to a wearable device including:

a camera that receives an image of a user's eye; a wireless communication unit that sends and receives data by communicating with at least one lighting device; and a wearable device controller that detects a pupil image based on the image of the user's eye, generates a control signal for controlling the level of illumination of the lighting device, and controls the wireless communication unit to transmit the control signal to the lighting device.

The effects of at least one exemplary embodiment of the present invention having the above-described configuration are as follows:

First, a lighting system according to an exemplary embodiment of the present invention can receive images of a user's eye and control lighting based on the images of the eye. Accordingly, the present invention has an active lighting control effect.

Second, the right level of illumination suitable for the user can be provided by controlling lighting according to pupil size.

Third, the lighting system according to the exemplary embodiment of the present invention actively controls lighting according to a pupil image. Accordingly, the present invention can increase user convenience.

The effects of the present invention are not limited to the above-mentioned effects, and other effects not mentioned above can be clearly understood from the definitions in the claims by one skilled in the art.

Furthermore, although the exemplary embodiments of the present invention have been shown and described, the present invention is not limited to the above specific embodiments, and a person having ordinary skill in the art to which the invention belongs may modify the embodiments in various ways without deuniting from the gist of the present invention which is written in the claims. The modified embodiments should not be interpreted individually from the technical spirit or prospect of the present invention.

Any reference in this specification to "one embodiment," "an embodiment," "example embodiment," etc., means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the invention. The appearances of such phrases in various places in the specification are not necessarily all referring to the same embodiment. Further, when a particular feature, structure, or characteristic is described in connection with any embodiment, it is submitted that it is within the purview of one skilled in the art to effect such feature, structure, or characteristic in connection with other ones of the embodiments.

Although embodiments have been described with reference to a number of illustrative embodiments thereof, it should be understood that numerous other modifications and embodiments can be devised by those skilled in the art that will fall within the spirit and scope of the principles of this disclosure. More particularly, various variations and modifications are possible in the component parts and/or arrangements of the subject combination arrangement within the scope of the disclosure, the drawings and the appended claims. In addition to variations and modifications in the component parts and/or arrangements, alternative uses will also be apparent to those skilled in the art.

What is claimed is:

1. A lighting device comprising:

a communication unit to communicate with a wearable device having at least one camera, the communication unit to receive an image of a user's eye captured by the camera;

a light emitting unit that includes one or more light emitting elements; and

a controller to detect a pupil image based on the image of the user's eye and to control the light emitting unit based on the pupil image,

wherein the controller includes an image processor to detect the pupil image based on the image of the user's eye and to determine a level of illumination corresponding to a size of the detected pupil image by comparing the pupil image with preset first and second reference values,

wherein the image processor includes:

an object detector to detect the pupil image from the image of the user's eye,

an object recognizer to compare the size of the pupil image with the preset first and second reference values, and

an application unit to determine the level of illumination based on a result of the comparison.

2. The lighting device of claim **1**, wherein the object detector detects a plurality of pupil images from a plurality of images of the user's eye, and

the object recognizer determines an average pupil size of the plurality of pupil images and compares the average pupil size with the preset first and second reference values.

3. The lighting device of claim **1**, wherein when the size of the pupil image is greater than or equal to the first reference value, the controller increases the level of illumination from the light emitting unit.

4. The lighting device of claim **1**, wherein when the size of the pupil image is less than or equal to the second reference value, the controller decreases the level of illumination from the light emitting unit.

5. The lighting device of claim **1**, wherein the controller includes an image processor to detect the pupil image based on the image of the user's eye and to determine a level of illumination corresponding to a position of the detected pupil image by comparing the pupil image with a preset reference value.

6. The lighting device of claim **5**, wherein when the position of the pupil image is located above the reference value, the controller increases the level of illumination from the light emitting unit.

7. The lighting device of claim **5**, wherein when the position of the pupil image is located below the reference value, the controller decreases the level of illumination from the light emitting unit.

8. The lighting device of claim **5**, wherein the image processor includes:

an object recognizer to compare the position of the pupil image with the reference value;

an object tracker to determine a change in the position of the pupil image based on a result of the comparison of the position of the pupil image and the reference value; and

an application unit to determine the level of illumination corresponding to the change in the position.

9. The lighting device of claim **8**, wherein the object detector detects a plurality of pupil images from a plurality of images of the user's eye, and

the object recognizer determines an average position of the plurality of pupil images and compares the average position with the reference value.

10. A lighting system comprising:

a plurality of lighting devices, each lighting device including one or more light emitting units; and an integrated control module to communicate with a wearable device having at least one camera, the integrated control module to receive an image of a user's eye captured by the camera, to detect a pupil image based on the image, and to control a number of lighting devices to be activated among the plurality of lighting devices based on the pupil image,

wherein the integrated control module includes an image processor to detect the pupil image based on the image of the user's eye and to determine a level of illumination corresponding to a size of the detected pupil image by comparing the pupil image with preset first and second reference values,

wherein the integrated control module further includes an integrated control module communication unit to communicate with the wearable device and the plurality of lighting devices, and

the image processor includes:

an object detector to detect the pupil image from the image of the user's eye,

an object recognizer to compare the size of the pupil image with the first and second reference values, and

an application unit to determine a number of lighting devices to be activated based on the size of the detected pupil image.

11. A wearable device comprising:

a camera to receive an image of a user's eye;

a wireless communication unit to send and receive data by communicating with at least one lighting device; and

a wearable device controller to detect a pupil image based on the image of the user's eye, to generate a control signal for controlling a level of illumination of the lighting device, and to control the wireless communication unit to transmit the control signal to the lighting device,

wherein the wearable device controller includes an image processor to detect the pupil image based on the image of the user's eye and to determine the level of illumination corresponding to a size of the detected pupil image by comparing the pupil image with preset first and second reference values,

wherein the image processor includes:

an object detector to detect the pupil image from the image of the user's eye,

an object recognizer to compare the size of the pupil image with the first and second reference values, and

an application unit to determine the level of illumination corresponding to a result of the comparison.

12. The wearable device of claim **11**, wherein the camera obtains a plurality of images of the user's eye,

the object detector detects a plurality of pupil images from a plurality of images of the user's eye, and

the object recognizer determines an average pupil size of the plurality of pupil images and compares the average pupil size with the first and second reference values.

13. The wearable device of claim **11**, wherein the image processor to determine the level of illumination corresponding to a position of the detected pupil image by comparing the pupil image with a reference value.

14. The wearable device of claim **13**, wherein the image processor includes:

the object detector to detect the pupil image from the image of the user's eye;

the object recognizer to compare the position of the pupil image with the reference value;

an object tracker to determine a change in the position of the pupil image based on a result of the comparison of the position of the pupil image and the reference value; and

an application unit to determine the level of illumination corresponding to the change in the position.

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